

## DECLARATION OF DR. RANDELL L. MILLS

I, Randell L. Mills, declare and state as follows:

1. I am the founder and CEO of BlackLight Power, Inc., located at 493 Old Trenton Road, Cranbury, New Jersey 08512.
2. I majored in chemistry and received my bachelor of arts degree, *summa cum laude* and Phi Beta Kappa, from Franklin & Marshall College in 1982. I received a medical degree from Harvard Medical School in 1986. While attending Harvard Medical School, I concurrently spent a year taking courses in advanced electrical engineering at the Massachusetts Institute of Technology. I have also had significant academic training in biology, chemistry, mathematics and physics.
3. I began my research in the field of energy technology over ten years ago. I have authored, co-authored or collaborated on numerous publications, reports and presentations at scientific meetings in the field of energy technology and novel hydrogen chemistry, as shown in the attachment hereto.
4. I am fully qualified to conduct the research that led to the discovery and development of BlackLight's lower-energy hydrogen technology.
5. I personally conducted and/or supervised the experimental data disclosed in the articles submitted to the U.S. Patent and Trademark Office ("PTO"), which are described in the attached list. The coauthors, if any, assisted me in preparing the data.

I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

By   
Dr. Randell L. Mills

Date: 26 October 2004

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### **Book Publications**

8. R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 2003 Edition, BlackLight Power, Inc., Cranbury, New Jersey, posted at [www.blacklightpower.com](http://www.blacklightpower.com).
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### **Correspondence**

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### **Test Reports**

Numerous test reports are available from BlackLight Power (e.g. Haldeman, C. W., Savoye, G. W., Iseler, G. W., Clark, H. R., MIT Lincoln Laboratories Excess Energy Cell Final report ACC Project 174 (3), April 25, 1995; Peterson, S., H., Evaluation of Heat Production from Light Water Electrolysis Cells of HydroCatalysis Power Corporation, Report from Westinghouse STC, 1310 Beulah Road, Pittsburgh, PA, February 25, 1994; Craw-Ivanco, M. T.; Tremblay, R. P.; Boniface, H. A.; Hilborn, J. W.; "Calorimetry for a Ni/K<sub>2</sub>CO<sub>3</sub> Cell," Atomic Energy Canada Limited, Chemical Engineering Branch, Chalk River Laboratories, Chalk River, Ontario, June 1994; Nesterov, S. B., Kryukov, A. P., Moscow Power Engineering Institute Affidavit, February, 26, 1993; Jacox, M. G., Watts, G. R., "The Search for Excess Heat in the Mills Electrolytic Cell," Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho, 83415, January 7, 1993; Gernert, N., Shaubach, R. M., Mills, R., Good, W., "Nascent Hydrogen: An Energy Source," Final Report prepared by Thermacore, Inc., for the Aero Propulsion and Power Directorate, Wright Laboratory, Air Force Material Command (ASC), Wright-Patterson Air Force Base, Contract Number F33615-93-C-2326, May, (1994); Phillips, J., Smith, J., Kurtz, S., "Report On Calorimetric Investigations Of Gas-Phase Catalyzed Hydrino Formation" Final report for Period October-December 1996," January 1, 1997, A Confidential Report submitted to BlackLight Power, Inc. provided by BlackLight Power, Inc., Great Valley Corporate Center, 41 Great Valley Parkway, Malvern, PA 19355; B. N. Popov, "Electrochemical Characterization of BlackLight Power, Inc. MH as Electrodes for Li-ion Batteries, Dept. of Chemical Engineering, University of South Carolina, February

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### **Prior Conference Presentations**

52. R. L. Mills, Y. Lu, M. Nansteel, J. He, A. Voigt, B. Dhandapani, "Energetic Catalyst-Hydrogen Plasma Reaction as a Potential New Energy Source," Division of Fuel Chemistry, Session: Advances in Hydrogen Energy, 228th American Chemical Society National Meeting, August 22–26, 2004, Philadelphia, PA.
52. R. L. Mills, BlackLight Power—Technical Presentation, Volta Institute, June 25, 2004, Como, Italy.
51. R. L. Mills, Y. Lu, M. Nansteel, J. He, A. Voigt, B. Dhandapani, "Energetic Catalyst-Hydrogen Plasma Reaction as a Potential New Energy Source," Division of Fuel Chemistry, Session: Chemistry of Solid, Liquid, and Gaseous Fuels, 227th American Chemical Society National Meeting, March 28–April 1, 2004, Anaheim, CA.
50. R. L. Mills, P. Ray, M. Nansteel, J. He, X. Chen, A. Voigt, B. Dhandapani, "Energetic Catalyst-Hydrogen Plasma Reaction as a Potential New Energy Source," (Division of Industrial and Engineering Chemistry Symposium), September 9, 2003, 226<sup>th</sup> American Chemical Society National Meeting, (Sept. 7–11, 2003), New York, NY.
49. B. Dhandapani, R. Mills, "Novel Liquid-Nitrogen-Condensable Molecular Hydrogen Gas" (Physical Chemistry Session) , Wednesday, June 11, 2003, 36<sup>th</sup> Middle Atlantic Regional Meeting of American Chemical Society, (June 8–11, 2003), Princeton University, Princeton, NJ.
48. P. Ray, R. Mills, "Extreme Ultraviolet Spectroscopy of Helium-Hydrogen Plasma" (Physical Chemistry Session) , Wednesday, June 11, 2003, 36<sup>th</sup> Middle Atlantic Regional Meeting of American Chemical Society, (June 8–11, 2003), Princeton University, Princeton, NJ.
47. R. Mills, "Novel Catalytic Reaction Of Hydrogen as a Potential New Energy Source" (Catalysis Session), Tuesday, June 10, 2003, 36<sup>th</sup> Middle Atlantic Regional Meeting of American Chemical Society, (June 8–11, 2003), Princeton University, Princeton, NJ.
46. J. He, R. Mills, "TOF-SIMS and XPS Studies of Highly Stable Silicon Hydride Films" (Inorganic/Solid State Session), Monday, June 9, 2003, 36<sup>th</sup> Middle Atlantic

Regional Meeting of American Chemical Society, (June 8–11, 2003), Princeton University, Princeton, NJ.

45. B. Dhandapani, R. Mills, "Low Power MPCVD Synthesis and Characterization of Diamond Films on Silicon Substrates" (Inorganic/Solid State Session) , Monday, June 9, 2003, 36<sup>th</sup> Middle Atlantic Regional Meeting of American Chemical Society, (June 8–11, 2003), Princeton University, Princeton, NJ.
44. X. Chen, R. Mills, "Calorimetric Study of Heat Generation by Catalytic Reaction of Atomic Hydrogen in Resonant Transfer Plasmas" (Fuel Cells Session) , Monday, June 9, 2003, 36<sup>th</sup> Middle Atlantic Regional Meeting of American Chemical Society, (June 8–11, 2003), Princeton University, Princeton, NJ.
43. R. L. Mills, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Industrial and Engineering Chemistry, "Green Chemistry in the Design of Alternative Energy Strategies," symposium, Oral Presentation, 225<sup>th</sup> ACS National Meeting, (March 23-27, 2003), New Orleans, LA.
42. R. L. Mills, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Monday, November 25, Room 216, Protocol Center, TA-3, Los Alamos National Laboratory.
41. R. L. Mills, "Classical Quantum Mechanics," Monday, November 25, Room 216, Protocol Center, TA-3, Los Alamos National Laboratory.
40. R. L. Mills, Seminar: "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," US Environmental Protection Agency, National Risk Management Research Laboratory, Sustainable Technologies Division, Cincinnati, OH, October 24, 2002.
39. R. L. Mills, J. Dong, J. He, B. Dhandapani, A. Voigt, M. Nansteel, J. Sankar, R. M. Mayo, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Inorganic Chemistry, Oral Presentation, 224<sup>rd</sup> ACS National Meeting, (August 18-22, 2002), Boston, MA (Aug. 22, 4:10-4:30 PM).
38. R. L. Mills, J. Dong, J. He, B. Dhandapani, A. Voigt, M. Nansteel, J. Sankar, R. M. Mayo, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Colloidal and Surface Chemistry, Oral Presentation, 224<sup>rd</sup> ACS National Meeting, (August 18-22, 2002), Boston, MA (Aug. 22, 8:30-8:50 AM).
37. P. Ray, R. Mills, "Spectroscopic Characterization of Stationary Inverted Balmer and Lyman Populations Formed by a Catalytic Reaction of Atomic Hydrogen with

Oxygen and with Certain Group I Catalysts," Eighteenth International Conference on Atomic Physics, July 28-August 2, 2002, Cambridge, Massachusetts.

36. R. M. Mayo, R. L. Mills, M. Nansteel, "Direct Plasmadynamic Conversion of Plasma Thermal Power from a Novel Plasma Source to Electricity for Microdistributed Power Applications," 40<sup>th</sup> Power Sources Conference, (June 6–13, 2002), Cherry Hill, NJ.
35. R. L. Mills, J. Dong, J. He, B. Dhandapani, W. Good, A. Voigt, S. Hicks, M. Nansteel, E. Dayalan, P. Ray, "Spectroscopic Identification of a Novel Catalytic Reaction of Hydrogen," Division of Inorganic Chemistry, Oral Presentation, 223<sup>rd</sup> ACS National Meeting, (April 7–11, 2002), Orlando, FL.
34. R. L. Mills, J. Dong, J. He, B. Dhandapani, W. Good, A. Voigt, S. Hicks, M. Nansteel, E. Dayalan, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Inorganic Chemistry, Oral Presentation, 223<sup>rd</sup> ACS National Meeting, (April 7–11, 2002), Orlando, FL.
33. R. L. Mills, J. Dong, J. He, B. Dhandapani, W. Good, A. Voigt, S. Hicks, M. Nansteel, E. Dayalan, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Industrial and Engineering Chemistry, Oral Presentation, 223<sup>rd</sup> ACS National Meeting, (April 7–11, 2002), Orlando, FL.
32. R. L. Mills, J. Dong, J. He, B. Dhandapani, W. Good, A. Voigt, S. Hicks, M. Nansteel, E. Dayalan, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Catalysis and Surface Science Secretariat, Oral Presentation, 223<sup>rd</sup> ACS National Meeting, (April 7–11, 2002), Orlando, FL.
31. R. L. Mills, J. Dong, J. He, B. Dhandapani, W. Good, A. Voigt, S. Hicks, M. Nansteel, E. Dayalan, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Physical Chemistry, Poster Presentation, 223<sup>rd</sup> ACS National Meeting, (April 7–11, 2002), Orlando, FL.
30. R. L. Mills, J. Dong, J. He, B. Dhandapani, W. Good, A. Voigt, S. Hicks, M. Nansteel, E. Dayalan, P. Ray, "Novel Catalytic Reaction of Hydrogen as a Potential New Energy Source," Division of Physical Chemistry, Sci-Mix Poster Presentation, 223<sup>rd</sup> ACS National Meeting, (April 7–11, 2002), Orlando, FL.
29. R. Mills, "BlackLight Power Technology-A New Clean Energy Source with the Potential for Direct Conversion to Electricity," *The 8 th Annual Emerald Groundhog Day Investment Forum*, February 5, 2002, Wyndham Franklin Plaza Hotel, Philadelphia, PA, Organized by Emerald Asset Management, Lancaster, PA.

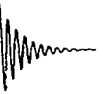
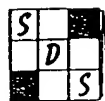
28. R. L. Mills, E. Dayalan, "Novel Alkali and Alkaline Earth Hydrides for High Voltage and High Energy Density Batteries," Proceedings of the 17<sup>th</sup> Annual Battery Conference on Applications and Advances, California State University, Long Beach, CA, (January 15-18, 2002), pp. 1-6.
27. P. Ray, R. Mills, "Spectroscopic identification of a novel catalytic reaction of hydrogen plasma," Session ET1: Lighting, American Physical Society Meeting, 54<sup>th</sup> Annual Gaseous Electronics Conference, October 9-12, 2001, Pennsylvania State University, State College, PA.
26. R. Mills, "Novel catalytic reaction of hydrogen as a potential new energy source," Division of Industrial and Engineering Chemistry; Session: Industrial Bio-Based Technology, 222<sup>nd</sup> American Chemical Society Fall National Meeting, (August 26-30, 2001), Chicago, IL.
25. R. Mills, "Spectroscopic identification of a novel catalytic reaction of hydrogen," Division of Inorganic Chemistry; Session: Catalysis, 222<sup>nd</sup> American Chemical Society Fall National Meeting, (August 26-30, 2001), Chicago, IL.
24. R. Mills, "Spectroscopic identification of a novel catalytic reaction of hydrogen," Division of Physical Chemistry; Session: Physical Chemistry Poster Session, 222<sup>nd</sup> American Chemical Society Fall National Meeting, (August 26-30, 2001), Chicago, IL.
23. R. Mills, J. He, "Spectroscopic Identification of a Novel Catalytic Reaction of Atomic Hydrogen and the Hydride Ion Product," National Hydrogen Association, 12<sup>th</sup> Annual U.S. Hydrogen Meeting and Exposition, *Hydrogen: The Common Thread*, The Washington Hilton and Towers, Washington DC, (March 6-8, 2001).
22. R. Mills, B. Dhandapani, M. Nansteel, N. Greenig, S. Hicks, J. Dong, "Optically Measured Power Balances of Anomalous Discharges of Mixtures of Argon, Hydrogen, and Potassium, Rubidium, Cesium, or Strontium Vapor," National Hydrogen Association, 12<sup>th</sup> Annual U.S. Hydrogen Meeting and Exposition, *Hydrogen: The Common Thread*, The Washington Hilton and Towers, Washington DC, (March 6-8, 2001).
21. R. Mills, M. Nansteel, N. Greenig, S. Hicks, "BlackLight Power Technology-A New Clean Energy Source with the Potential for Direct Conversion to Electricity," National Hydrogen Association, 12<sup>th</sup> Annual U.S. Hydrogen Meeting and Exposition, *Hydrogen: The Common Thread*, The Washington Hilton and Towers, Washington DC, (March 6-8, 2001).



20. R. Mills, B. Dhandapani, M. Nansteel, J. He, A. Voigt, "Identification of Compounds Containing Novel Hydride Ions by Nuclear Magnetic Resonance Spectroscopy," National Hydrogen Association, 12 th Annual U.S. Hydrogen Meeting and Exposition, *Hydrogen: The Common Thread*, The Washington Hilton and Towers, Washington DC, (March 6-8, 2001).
19. R. Mills, "BlackLight Power Technology-A New Clean Energy Source with the Potential for Direct Conversion to Electricity," *The 8 th Annual Emerald Groundhog Day Investment Forum*, February 1, 2001, Wyndham Franklin Plaza Hotel, Philadelphia, PA, Organized by Emerald Asset Management, Lancaster, PA.
18. R. Mills, "The Grand Unified Theory of Classical Quantum Mechanics," Global Foundation, Inc. Orbis Scientiae entitled *The Role of Attractive and Repulsive Gravitational Forces in Cosmic Acceleration of Particles The Origin of the Cosmic Gamma Ray Bursts*, (29th Conference on High Energy Physics and Cosmology Since 1964) Dr. Behram N. Kursunoglu, Chairman, December 14-17, 2000, Lago Mar Resort, Fort Lauderdale, FL.
17. R. Mills, "BlackLight Power Technology-A New Clean Energy Source with the Potential for Direct Conversion to Electricity," Global Foundation, Inc. conference entitled *Global Warming and Energy Policy*, Fort Lauderdale, FL, November 26-28, 2000.
16. R. Mills, B. Dhandapani, N. Greenig, J. He, J. Dong, Y. Lu, and H. Conrads, "Formation of an Energetic Plasma and Novel Hydrides from Incandescently Heated Hydrogen Gas with Certain Catalysts," August National ACS Meeting (220th ACS National Meeting, Washington, DC, (August 20-24, 2000)).
15. R. Mills, J. He, and B. Dhandapani, "Novel Alkali and Alkaline Earth Hydrides," August National ACS Meeting (220th ACS National Meeting, Washington, DC, (August 20-24, 2000)).
14. R. Mills, B. Dhandapani, N. Greenig, J. He, J. Dong, Y. Lu, and H. Conrads, "Formation of an Energetic Plasma and Novel Hydrides from Incandescently Heated Hydrogen Gas with Certain Catalysts," June ACS Meeting (29th Northeast Regional Meeting, University of Connecticut, Storrs, CT, (June 18-21, 2000)).
13. Mills, J. Dong, N. Greenig, and Y. Lu, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts," 219 th National ACS Meeting, San Francisco, California, (March 26-30, 2000).
12. R. Mills, B. Dhandapani, N. Greenig, J. He, J. Dong, Y. Lu, and H. Conrads, "Formation of an Energetic Plasma and Novel Hydrides from Incandescently Heated

- Hydrogen Gas with Certain Catalysts," 219 th National ACS Meeting, San Francisco, California, (March 26-30, 2000).
11. R. Mills, "Novel Hydride Compound," 219 th National ACS Meeting, San Francisco, California, (March 26-30, 2000).
  10. R. Mills, J. He, and B. Dhandapani, "Novel Alkali and Alkaline Earth Hydrides," 219 th National ACS Meeting, San Francisco, California, (March 26-30, 2000).
  9. R. Mills, J. Dong, N. Greenig, and Y. Lu, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts," National Hydrogen Association, 11 th Annual U.S. Hydrogen Meeting, Vienna, VA, (February 29-March 2, 2000).
  8. R. Mills, B. Dhandapani, N. Greenig, J. He, J. Dong, Y. Lu, and H. Conrads, "Formation of an Energetic Plasma and Novel Hydrides from Incandescently Heated Hydrogen Gas with Certain Catalysts," National Hydrogen Association, 11 th Annual U.S. Hydrogen Meeting, Vienna, VA, (February 29-March 2, 2000).
  7. R. Mills, "Novel Hydride Compound," National Hydrogen Association, 11 th Annual U.S. Hydrogen Meeting, Vienna, VA, (February 29-March 2, 2000).
  6. R. Mills, J. He, and B. Dhandapani, "Novel Alkali and Alkaline Earth Hydrides," National Hydrogen Association, 11 th Annual U.S. Hydrogen Meeting, Vienna, VA, (February 29-March 2, 2000).
  5. R. Mills, J. Dong, Y. Lu, J. Conrads, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts," 1999 Pacific Conference on Chemistry and Spectroscopy and the 35th ACS Western Regional Meeting, Ontario Convention Center, California, (October 6-8, 1999).
  4. R. Mills, "Novel Hydride Compound," 1999 Pacific Conference on Chemistry and Spectroscopy and the 35th ACS Western Regional Meeting, Ontario Convention Center, California, (October 6-8, 1999).
  3. R. Mills, B. Dhandapani, N. Greenig, J. He, "Synthesis and Characterization of Potassium Iodo Hydride," 1999 Pacific Conference on Chemistry and Spectroscopy and the 35th ACS Western Regional Meeting, Ontario Convention Center, California, (October 6-8, 1999).
  2. R. Mills, J. He, and B. Dhandapani, "Novel Hydrogen Compounds," 1999 Pacific Conference on Chemistry and Spectroscopy and the 35th ACS Western Regional Meeting, Ontario Convention Center, California, (October 6-8, 1999).

1. R. Mills, "Excess Heat Production by the Electrolysis of an Aqueous Potassium Carbonate Electrolyte," August 1991 meeting of the American Chemical Society, NY, NY.



*SPECTRAL DATA SERVICES, INC.*

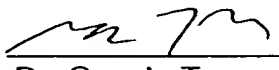
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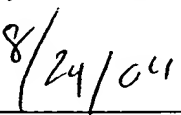
## DECLARATION OF DR. GARY L. TURNER

I, Gary L. Turner, declare and state that:

1. I received a Bachelor of Science degree in Chemistry from the University of Illinois, Urbana, Illinois in 1978 and a Doctorate degree in Physical Chemistry at the University of Arkansas, Fayetteville, Arkansas in 1982.
2. From July 1982 to June 1988, I was a research associate for Dr. E. Oldfield, at the University of Illinois, Urbana, Illinois.
3. From August 1985 to the present, I have been employed by Spectral Data Services, Inc., where my duties include obtaining Nuclear-Magnetic-Resonance data on sample materials.
4. From April 1986 to August 1990 I was also employed as the Vice-President of Probe Systems, Inc., where I was responsible for designing Nuclear-Magnetic-Resonance (NMR) equipment.
5. I have published 38 peer-reviewed scientific papers, a list of which is shown in the Attachment.
6. Over the last year, I obtained  $^1\text{H}$  MAS NMR data on about 300 blind samples of compounds provided by BlackLight Power, Inc.
7. A 270 MHz NMR Spectrometer, operating at a Larmor frequency of 270.6196 MHz was used. The spectrometer was equipped with a Tecmag operating system and Henry Radio amplifiers for pulse generation. The probe was a 7 mm Doty Scientific Standard Probe. The data was collected with a pulse angle of about  $15^\circ$ , with a two second delay between pulses. The samples were spun at two speeds, usually at 4.5 and 3.5 KHz, to identify the spinning sidebands. Typically, 200 transients were collected for each spectrum. The data was processed using NUTS (Acorn NMR, Inc.) software.
8. Some of the samples showed signals in regions that are not typical. Most  $^1\text{H}$  MAS NMR signals are observed from about 10 to 0 ppm, where ppm represents the shift from the chemical shift standard, tetramethylsilane. Signals for BLP samples were observed at -4 to -5 ppm. Since 1978, I have been primarily conducting NMR scans and I have never observed signals in the region of -4 to -5 ppm before.

9. For sample 080304BLP1, in the  $^1\text{H}$  MAS NMR spectrum two unusual signals were observed, at -4.1 and -4.5 ppm. The only compounds known to have chemical shifts in this region are transition metal hydrides, in particular  $\text{Mg}_2\text{NiH}_4$ . Elemental analysis (Galbraith Laboratories, Inc., Knoxville, TN) showed that Mg and Ni are not detected in this sample, and that K was the main metal present. Earlier NMR data has shown that the hydride of K appears at about 1.0 ppm. Therefore, these results suggest that the signals at -4.1 and -4.5 ppm represent a novel species, and do not correspond to any known metal hydride.
10. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

By   
Dr. Gary L. Turner

Date: 

## DECLARATION OF DR. BALA DHANDAPANI

I, Bala Dhandapani, residing at 30 Marion Circle, Eastampton, NJ 08060, declare and state that:

1. I received a Bachelor of Science Degree in Chemical Engineering from Anna University, Madras, India. I received a Doctorate Degree in Chemical Engineering in 1993 and a Masters of Science Degree in Chemical Engineering in 1990 from the Clarkson University, Potsdam, NY.

2. From 1997 to present, I have been employed as a Project Manager at BlackLight Power Inc., Cranbury, NJ, where I manage and conduct synthesis and characterization of novel hydride compounds.

3. From 1994-1997, I was employed as a Postdoctoral Research Associate and Laboratory Coordinator at Virginia Tech, Blacksburg, VA, Environmental Catalysis and Materials Laboratory, where I conducted synthesis, characterization, testing and development of novel catalytic materials for various environmentally significant reactions. I also managed the research activities of the lab of 12 researchers, including doctoral, masters and undergraduate students.

4. From 1990 - 1993, I was employed as a Research Assistant at Clarkson University, Potsdam, NY, wherein I studied the application of foam and monolith substrates for environmental catalysis. I also designed and constructed a reactor system with advanced instrumentation.

5. From 1988-1990, I was employed as an Instructor/Teaching Assistant at Clarkson University, where I taught the following courses: Unit Operations Laboratory, Reaction Engineering and Analysis, Advanced Reactor Design, Heterogeneous Catalysis, Material Science and Corrosion Engineering Laboratory.

6. I am experienced on the following instrumentation: AMETEK Quad Mass Spectrometer; Varian 3700 Gas Chromatograph; ISI-40 Scanning Electron Microscope; Siemens D 500 X-ray Diffractometer; Micromeritics ASAP 2010 Chemi; CHNS-EA1180 Elemental Analyzer; Perkin Elmer PHI 5300 ESCA; BioRad FT-60 Infrared spectroscopy; Mariner ESI-ToF Mass Spectrometer; HP 5890 and 6890 Gas Chromatograph; HP1100 HPLC; and Kratos XSAM800 XPS.

7. My research experience includes the synthesis of novel materials including: high surface area catalytic materials including monometallic and bimetallic transition metal carbides, nitrides, phosphides, hydrides and sulfides; noble metals and transition metal oxides; active catalytic materials supported on alumina, activated carbon, silica and titania; and high surface area activated carbon and silica from various precursors.

8. My research experience also includes the characterization of materials using the following techniques: X-ray diffraction; X-ray photoelectron spectroscopy; FTIR spectroscopy; Electrospray Ionization Time of Flight Mass Spectroscopy; Time of Flight Secondary Ion Mass Spectroscopy; Solids Probe Mass Spectroscopy (Quadrupole,

Magnetic Sector and Time of Flight); Proton Nuclear Magnetic Resonance; Scanning Electron Microscopy; Physisorption and Chemisorption techniques; Temperature programmed experiments; and Conductivity measurements Inductively Coupled Plasma Mass Spectrometry (elemental analysis).

9. My research experience further includes the development of catalytic materials, including: Optimization of synthesis conditions; Inclusion of additives, stabilizers and binders; and Fabrication of catalysts on monolith and foam substrates.

10. My research experience further includes the testing and evaluation of catalysts, including: Ozone decomposition reaction; Hydrogenation of aromatic compounds; Hydrodenitrogenation (HDN), hydrodesulfurization (HDS), hydrodeoxygenation (HDO) of various model compounds at high pressure reaction conditions; Hydrodechlorination (HDC) of chlorofluorocarbons; and Reforming of methane using membrane and plug flow reactors.

11. My research experience further includes kinetics and mechanism, including: Catalytic ozone decomposition reaction; Hydrogenation of isopropyl benzene; Simultaneous HDN, HDS and HDO of various heterocyclic aromatic compounds; and Hydrodechlorination of CFC-12 to HCFC-22 and HFC-32.

12. A selected list of my publications is attached.

13. I supervised the preparation of the compounds shown in the following Tables 1 and 2. Table 1 includes new compounds comprising hydrinos formed using catalysts for forming hydrinos (lower energy hydrogen) from hydrogen. The process used for forming the compounds comprising hydrinos is described in Dr. Randell L. Mills U.S. serial No. 09/009,294 and published PCT/US98/14029 application. Table 2 includes control compounds comprising conventional elements and energy states.

14. Blind samples of the compounds were sent to Dr. Gary L. Turner of Spectral Data Services, Inc. to conduct Nuclear-Magnetic-Resonance (NMR) evaluation of the samples. The results of the NMR analysis is shown in the Tables 1 and 2.

Summary of new hydrino hydride compounds that showed novel features with solid state MAS  $^1\text{H}$  NMR spectroscopy

Table 1

Compound	Data file	Reactants	$^1\text{H}$ NMR Features
KHI	blps00as.14	KI, K, $\text{H}_2$	-2.5*, 1.1
KHI	blps0095.005	K, KI, $\text{H}_2$	-3.2*, 0.9
KHCl	bpls99as.078	K, KCl, $\text{H}_2$	-4.4*, 4, 1.1
KHBr	bpls99as.058	K, KBr, $\text{H}_2$	-4.1*, 5.9, 4.3, 1.2
RbHF	bpls99as.034	RbF, K, $\text{H}_2$	-4.4*, 1.2

\* novel features

## Summary of relevant controls performed

Table 2

Control Compound	Data File	<sup>1</sup> H NMR Features
KH	blps00as.038	1.1, 0.8, 4.6
KH + KI	blps00as.099	1.1, 0.8, 4.5
KH + KCl	blps00as.097	1.1, 0.7, 4.3
KH + KBr	blps00as.101	1.1, 0.8, 4.2
RbH	textfr.1.txt	0.83, 4.0
RbH + RbF	blps00as.103	1.0, 4.9

1.1, 1.0, 0.8, 0.7 ppm is associated with M-H (where M is K or Rb),  
4-4.9 ppm is associated with M-OH (where M is K or Rb)

15. I analyzed XPS and TOFSIMS spectroscopy to determine the elements (cations and anions), such as the potassium and halides, present in each of the compounds. I also performed a Gas Chromatograph (GC) to determine whether hydrogen present in each of the compounds.

## CONCLUSIONS

16. Negative numbers in the compounds of Table 1 represent an upfield shift, which means that the electron is closer to the proton in the hydrogen. Thus, the upfield chemical shifts observed by the NMR data indicate that new lower energy states for the hydride ions (hydrino hydride ions) may exist.

17. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

By D. Dhandapani  
Dr. Bala Dhandapani

Date: 8/19/2000



## SELECTED PUBLICATIONS

J. Y. Wang, B. Dhandapani, D-T. Chin, An Experimental Study of Mass Transfer in Pulse Reversal Plating, *Journal of Applied Electrochemistry*, 22, 240, 1992.

D-T. Chin and B. Dhandapani, An Experimental Study of Metal Distribution in Pulse Plating, *Electrochimica Acta*, 37, 1927, 1992.

B. Dhandapani and S. T. Oyama, Novel Catalysts for Selective Dehalogenation of CCl<sub>2</sub>F<sub>2</sub> (CFC-12), *Catal. Lett.*, 35, 353, 1995.

B. Dhandapani and S. T. Oyama, Kinetics and Mechanism of Ozone Decomposition on Manganese Oxide Catalyst, *Chem. Lett.*, 413, 1995.

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## DECLARATION OF DR. JONATHAN PHILLIPS

For: VERIFICATION OF POWER GENERATION BASED ON DR. RANDELL L. MILLS' HYDRINO TECHNOLOGY

I, Jonathan Phillips, residing at 700 Avenida Castellano, Santa Fe, New Mexico, declare and state that:

1. I received a Bachelor of Arts degree in physics from Middlebury College, Middlebury, Vermont, in 1976, and a Masters of Science and Doctorate degrees in Materials Science at the University of Wisconsin, Madison, Wisconsin, in 1977 and 1981, respectively.
2. I have been a national lab professor at the University of New Mexico in the Department of Chemical and Nuclear Engineering since March 1999.
3. I am a technical staff member at Los Alamos National Lab, Los Alamos, New Mexico, where I serve as project leader on a material aging project.
4. I am currently on a two year leave of absence from my position as a full Professor of Chemical Engineering at the Pennsylvania State University, University Park, Pennsylvania, where I have been a member of the faculty since 1982.
5. I have published over 70 peer-reviewed scientific papers, and have conducted research for over 23 years in various areas, including multimetallic catalytic chemistry and structure, catalytic etching, carbon surface chemistry, plasma physics and chemistry, materials modification by plasmas, as well as microcalorimetry and Mossbauer spectroscopy. My research is currently supported by the U.S. National Science Foundation, the U.S. Department of Energy, and individual corporations through the NSF center for Ceramic and Composite Materials co-located at the University of New Mexico and Rutgers University.
6. I was a Fulbright Fellow at the Ben Gurion University of the Negev in 1997-98.
7. Experiments were conducted to test the hypothesis that in the gas phase potassium ions will catalyze the conversion of hydrogen atoms to hydrino atoms. These experiments were initially carried out in a Calvet cell as this type of calorimeter is highly sensitive and accurate. Moreover, the conditions of the calorimeter are controlled.
8. Dr. Randell L. Mill's theory of hydrino formation requires a catalyst, such as two gaseous  $K^+$  ions, and H-atoms. In order to generate gaseous  $K^+$  ions,  $KNO_3$  was placed in a small (2cc) quartz 'boat' inside the calorimeter cell. The boat was heated, to increase the vapor concentration of  $KNO_3$ , with a platinum filament, which

was wound around the boat. A second function of the platinum filament was to generate H-atoms. It is well known that hydrogen molecules in contact with a heated filament will decompose, yielding a relatively high H-atom concentration in the boundary layer around the filament. Thus, according to Dr. Mills' model, in a cell containing  $\text{KNO}_3$  in the boat and vapor phase hydrogen, there is a small region in the boundary layer around the heated metal filament which should contain sufficient concentrations of both H-atoms and  $\text{K}^+$  ions for hydrino formation to occur.

9. Calorimetric considerations require that a stable baseline exists before the heat generating process is initiated. Thus, signal change away from the baseline can be correlated to the onset of the process under investigation. In the present experiments the cell was run with  $\text{KNO}_3$  in the boat and the filament fully 'powered'. The calorimeter was allowed to equilibrate until a steady baseline existed. The 'hydrino formation' process was initiated by then adding gaseous hydrogen.
10. In the present experiment, data was obtained which indicates that heat evolved upon the introduction of hydrogen to the Calvet calorimeter cell. In contrast, no heat was evolved upon the admission of helium. Repeated calibrations were also conducted. Thus, it appears that the Dr. Mills' hypothesis is consistent with the present results.

## EXPERIMENTAL SYSTEM

11. Calvet Calorimeter. The Calvet-type calorimeter employed in this study was similar to one described in my earlier reports to Hydrocatalysis Corporation (now BlackLight Power, Inc.), entitled "Additional Calorimetric Examples of Anomalous Heat From Physical Mixture of K/Carbon and Pd/Carbon," January 1, 1996. In essence a stainless steel cup of almost exactly  $20 \text{ cm}^3$  volume was placed in a calorimeter well such that the cup is surrounded by thermopiles on its sides and bottom. The cup and calorimeter are surrounded by a thick layer of insulation, and the entire device is placed inside a commercial convection oven. In all cases experiments were conducted with the oven temperature set to  $250^\circ\text{C}$ .
12. Reaction cell. For these experiments the top of the calorimeter cup/reactor cell was fitted with a Conflat knife edge flange. The top element of the flange is connected to a gas supply system outside the convection oven with a 0.5 cm OD ss tube, and with two welded vacuum high current copper feedthroughs. The feedthroughs were connected on the cup side of the flange to a coiled section of 0.25 mm platinum wire approximately 18 cm in length. Fitted inside the coiled platinum was a small quartz boat into which 200 mg of powdered  $\text{KNO}_3$  were placed.
13. Plumbing. On the outside of the oven the gas feed through is connected to a line

leading to hydrogen and helium tanks, a pressure gauge, and a standard vacuum roughing pump. It is notable that the gas lines were all well insulated, both inside the oven, and for about 50 cm outside the oven. The plumbing system was so arranged that the cell could be evacuated, and then isolated from the pump in such a way that hydrogen or helium could be added directly from high purity gas tanks. Great care was taken before the experiments were initiated to evacuate and flush the gas lines several times. It was also determined that the lines held gas pressure, with no loss in pressure, for several days. That is, there were no leaks.

## RESULTS

14. Calvet Calorimeter. The Calvet studies suggest large amounts of heat are generated upon the admission of hydrogen to the cell. In contrast, virtually no heat is observed upon admission of helium to the cell.
15. Calibration. The first tests performed on the Calvet system were electrical calibration experiments. The system was set-up for full experimentation:  $\text{KNO}_3$  was in the boat, the system was evacuated, and 10 watts of steady power were supplied to the platinum coil. After a steady baseline was achieved (approximately 10 hours after the oven was adjusted to  $250^\circ\text{C}$ ), the cell was isolated from the pump and the pressure allowed to equilibrate (approximately 100 Torr). This did not appear to impact the baseline in any fashion. The power supply was then adjusted to deliver an additional 1 watt (11 watt rather than 10) for a specified time period. The power was then returned to the original 10 watt setting. A typical response curve is shown in Figure 1. The area under the response curve can be used to obtain a calibration constant which relates signal area increase to the number of extra Joules delivered. This was done in four cases (Table I). As can be seen, there is some error ( $\pm 15\%$ ) in the calculated calibration constant.
16. Control Studies. Helium was admitted, approximately 10 psig, to the cell to test the impact of a change in pressure, and heat transfer characteristics on the response of the cell. The helium was admitted after the cell had been isolated from the pump for a considerable time and a steady pressure (approximately 100 Torr) achieved. As can be seen in Figure 2a, the response was a short-lived small increase in output signal, followed by a relatively short time period during which the signal gradually returns to the original baseline. Within an hour the signal returned to the original baseline, with some drift evident.
17. The response of the system was expected. The helium increased the rate of heat transfer away from the platinum filament, and heated boat. Thus, the initial addition of helium to the system resulted in a temporary increase in the amount of heat reaching the thermopiles. That is, the boat and the filament cool off; until such time as the boat and filament have reached their new steady state temperatures. The

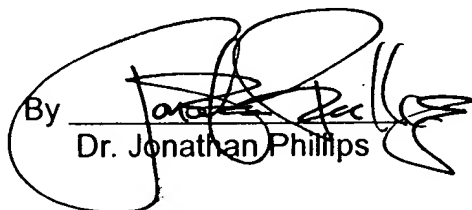
steady state temperature of the boat and filament are a function of heat transfer mechanism. After the admission of helium most heat transfer was occurring by convection to the walls. Before the admission of helium a considerable fraction was by radiation. Radiative transfer of 10 watts requires a higher filament/boat temperature than does convective heat transfer.

18. Figure 2b illustrates again the impact of adding pressure, or removing gas, from the system. Upon the addition of helium there was a very short lived increase in heat reaching the thermopiles. Upon pumping there was a period of time, perhaps an hour, during which the heat signal went below the baseline. This is consistent with the model in that pumping makes convective and diffusive heat transfer minimal. Virtually all heat transfer was by radiation, which requires that the filament/boat temperature increase. It took some time for this new steady-state temperature to be reached.
19. Hydrogen Admission. Hydrogen admission was carried out in much the same fashion as helium admission. The cell reached an equilibrium pressure, approximately 100 Torr, and then hydrogen at 10 psig was admitted to the cell. The valve to the hydrogen source, which was a steel line 4 meters by 0.6 cm OD, was closed off by a valve in front of the regulator during admission. Moreover, it was open for only a couple of seconds in each case. This was done on three separate occasions, and the signal that evolved in response to these three processes was recorded in Figures 3, 4 and 5. One other observation recorded was that the pressure decreased gradually over time, such that after about an hour the pressure returned to the original equilibrium pressure of the cell. It must also be noted that the heat production was ended deliberately in all three cases by pumping the system to  $5 \times 10^{-3}$  Torr. It is clear 'excess heat' evolution would have continued in all cases if the system had not been evacuated.
20. It was expected that in the absence of reaction that the response of the cell to the addition of hydrogen would be similar to that observed for helium. Indeed, given that pressure measurements suggest that most hydrogen was adsorbed, or in some other fashion removed from the cell after an hour, even heat transfer effects should be totally transitory. Even in the event of reaction no more than a small heat signal was expected. Indeed, a high end estimate is that  $25 \text{ cm}^3$  of hydrogen at a temperature of  $300^\circ\text{K}$  and a pressure of 2 atmospheres entered the cell. This is equivalent to  $2 \times 10^{-3}$  moles of hydrogen. If all of that hydrogen interacted with oxygen to form water only 510 J would be generated. It is possible to imagine that the hydrogen could interact with nitrogen in the  $\text{KNO}_3$  to form ammonia. However, even less energy would evolve from this process. Thus, the largest heat peak expected was 0.5 watts for 1000 seconds (approx. 17 minutes). A block of this size is marked on Figure 3.
21. It is clear from figures 3, 4 and 5 that hydrogen admission to the cell produced far

more energy evolution than can be explained by any conventional chemical process. It is interesting in this regard to graphically contrast the response of the system to helium admission to the response to that for hydrogen admission. This is done on Figure 6 in which Figure 3 and Figure 2a are superimposed.

## DISCUSSION

22. The evidence presented in this report clearly suggests that a phenomenon takes place upon the admission of hydrogen to a cell containing a heated platinum filament and  $\text{KNO}_3$ . This phenomenon appears to generate heat in excess of that expected from any known chemical process, given the content of the reactants in the cell.
23. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

By   
Dr. Jonathan Phillips

Date: July 20, 2000

Typical Calibration Experiment: 1 W Input, 20 Mins

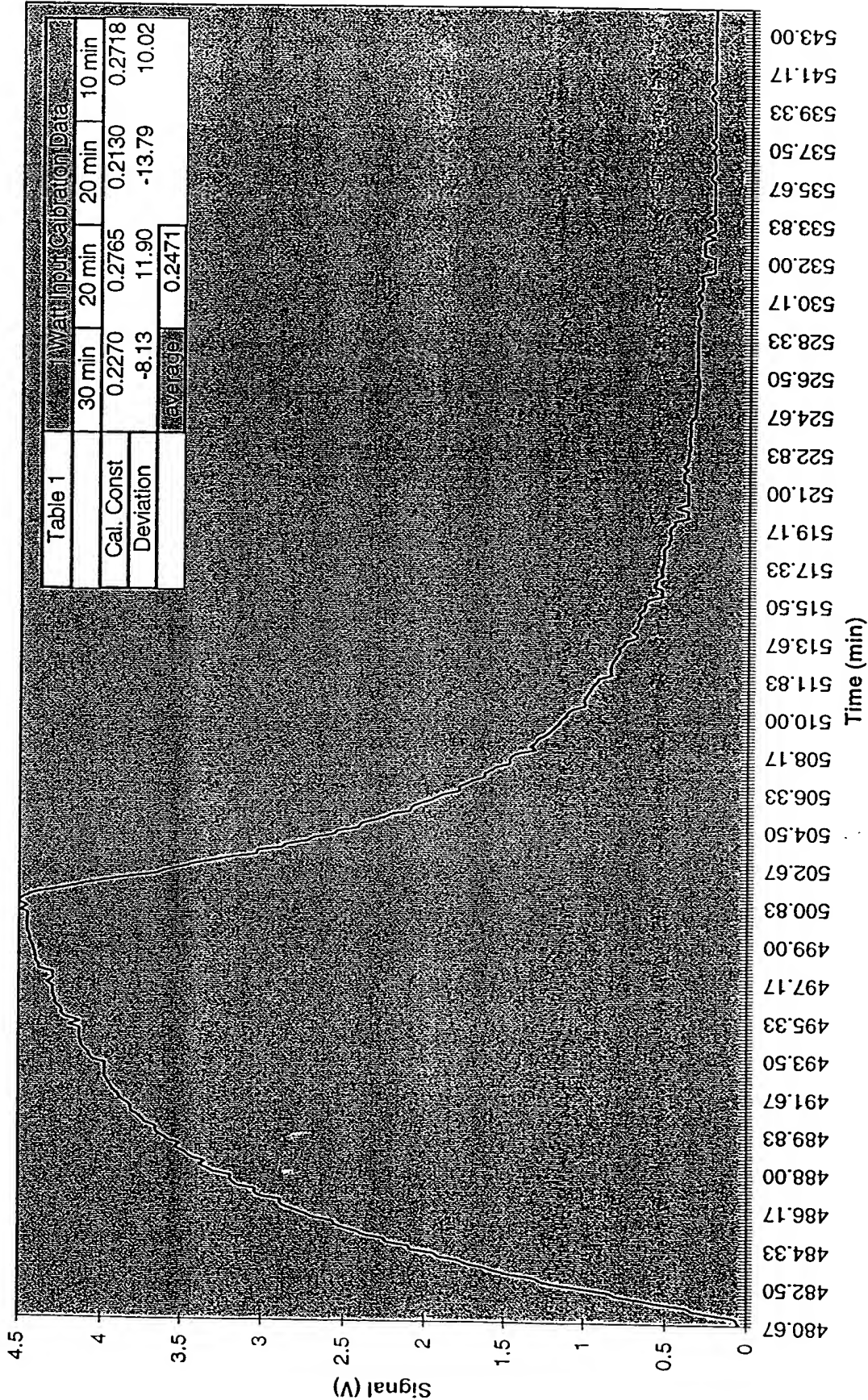


Figure 1



## Heat Production, KNO<sub>3</sub> w/ Helium Injection (BL1220A)

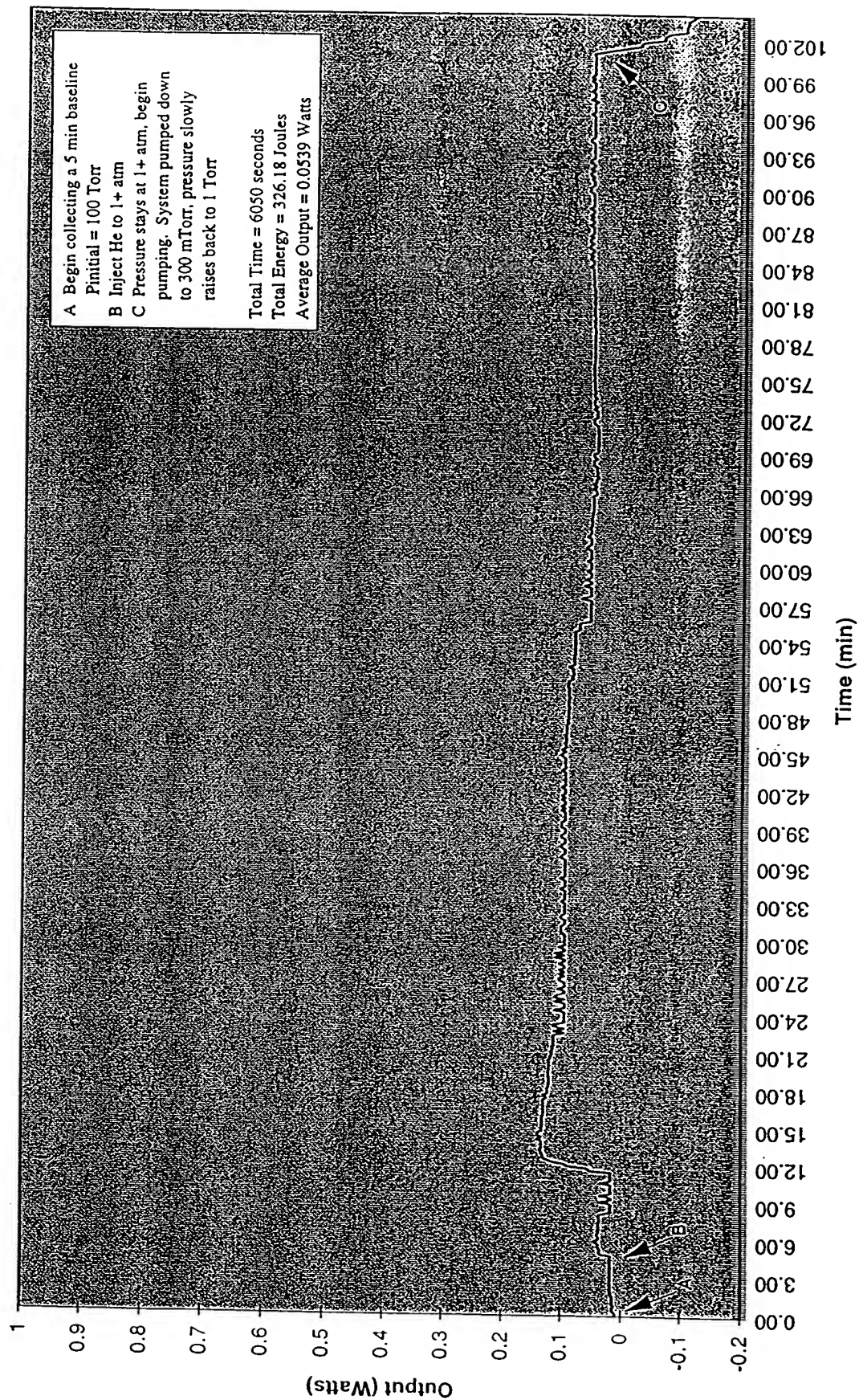


Figure 2A

# Heat Production, KNO3 w/ Helium Injection (BL1219B)

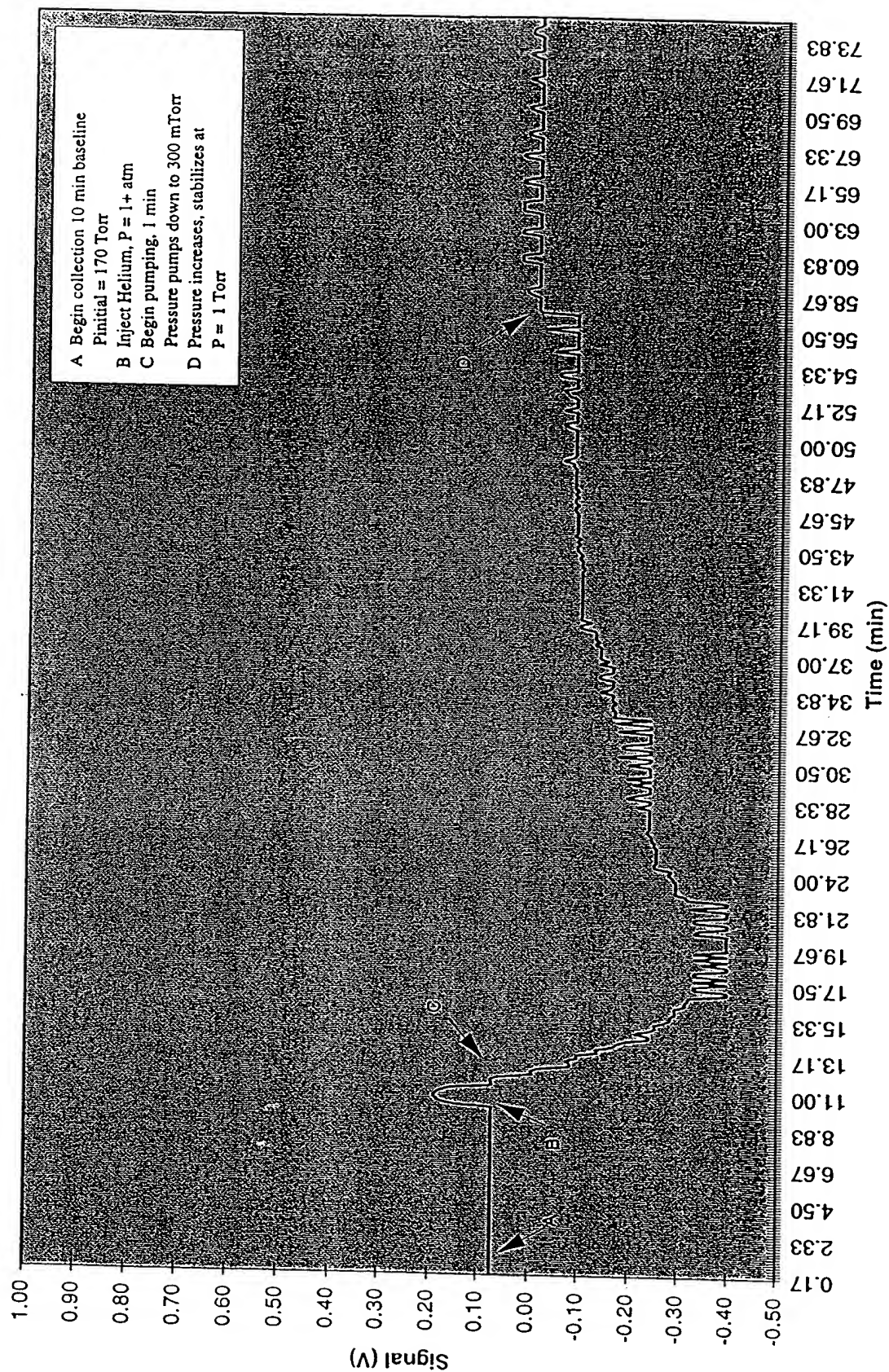
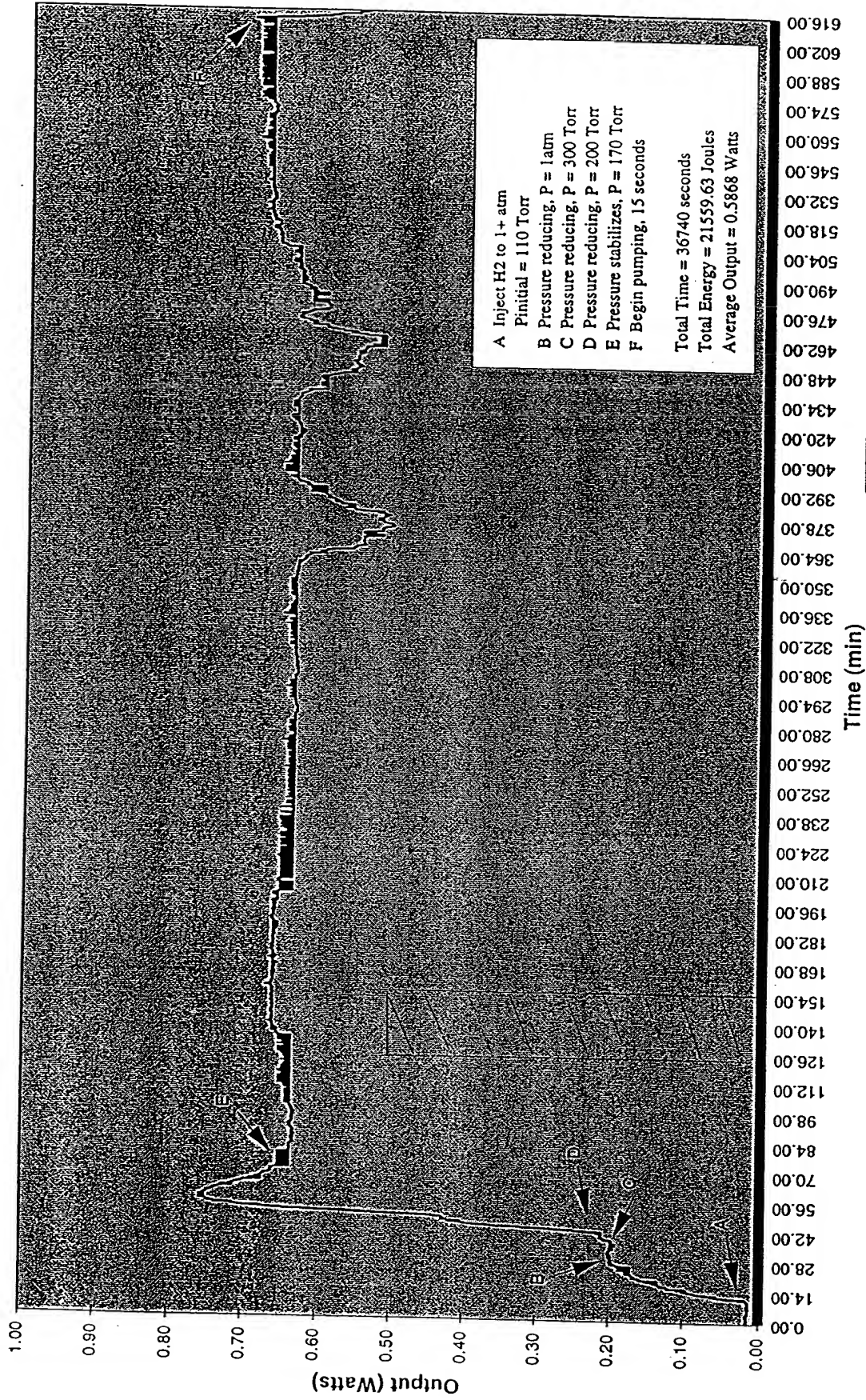


Figure 2B

Heat Production, KNO<sub>3</sub> w/ H<sub>2</sub> Injection (BL1218CD)



Peak area expected if  
all admitted H<sub>2</sub> reacts  
with O<sub>2</sub> to form H<sub>2</sub>O.

Figure 3



Heat Production, KNO3 w/ H2 Injection (BL1220BC)

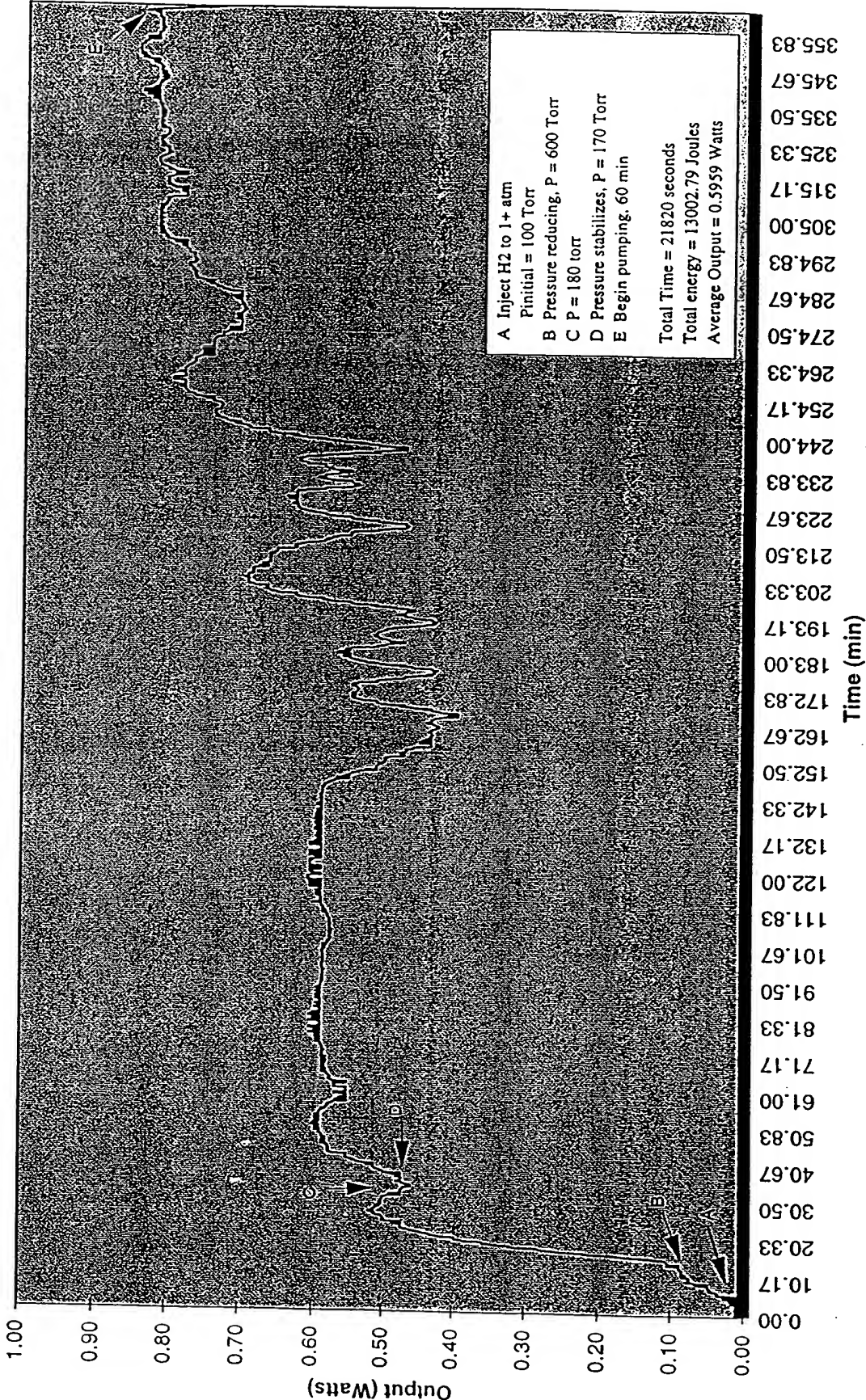


Figure 4

Heat Production, KNO3 w/ H2 Injection (BL1221AB)

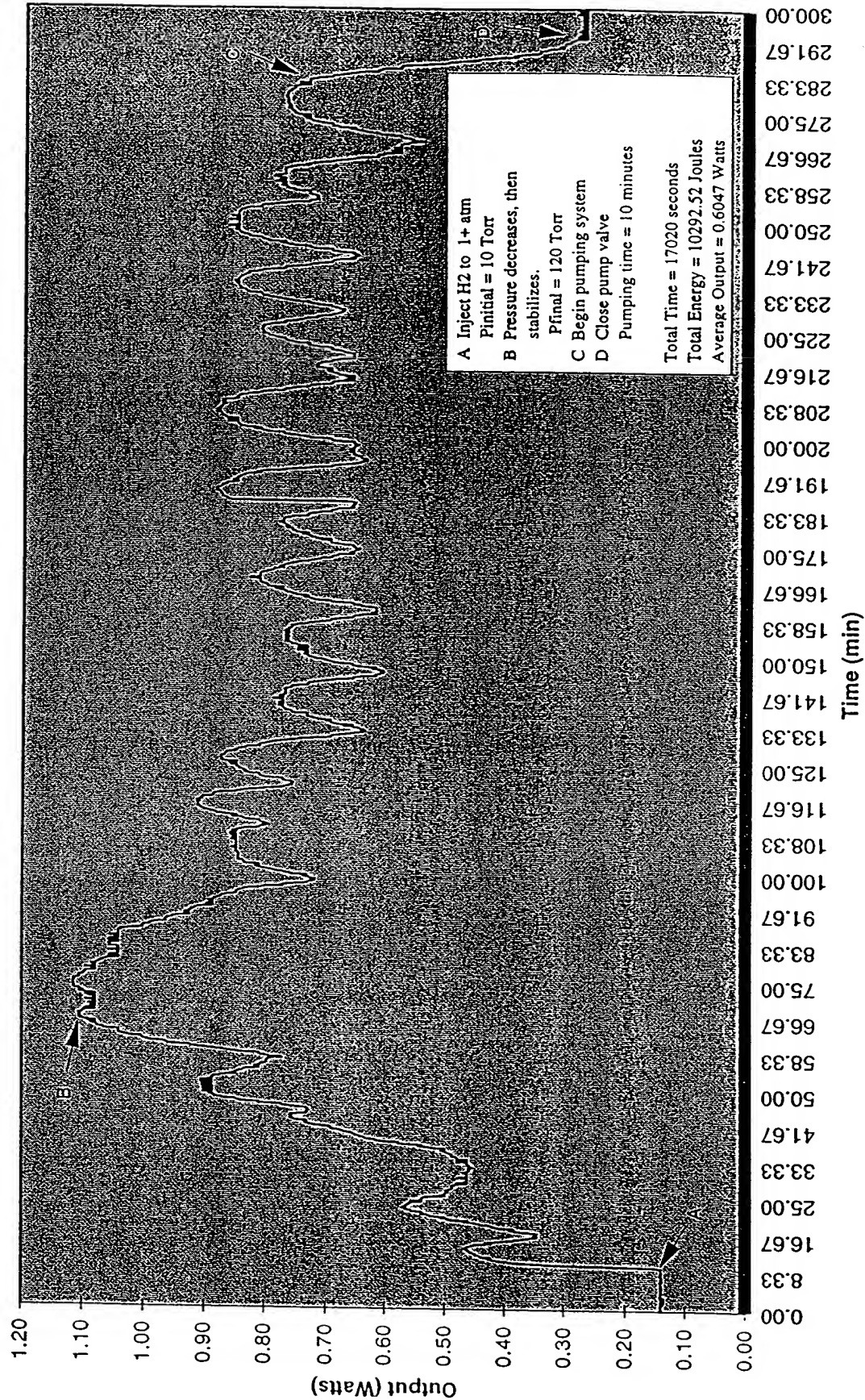


Figure 5

Heat Production, KNO3 w/ H2 and He Injection (BL1218CD,BL1219B)

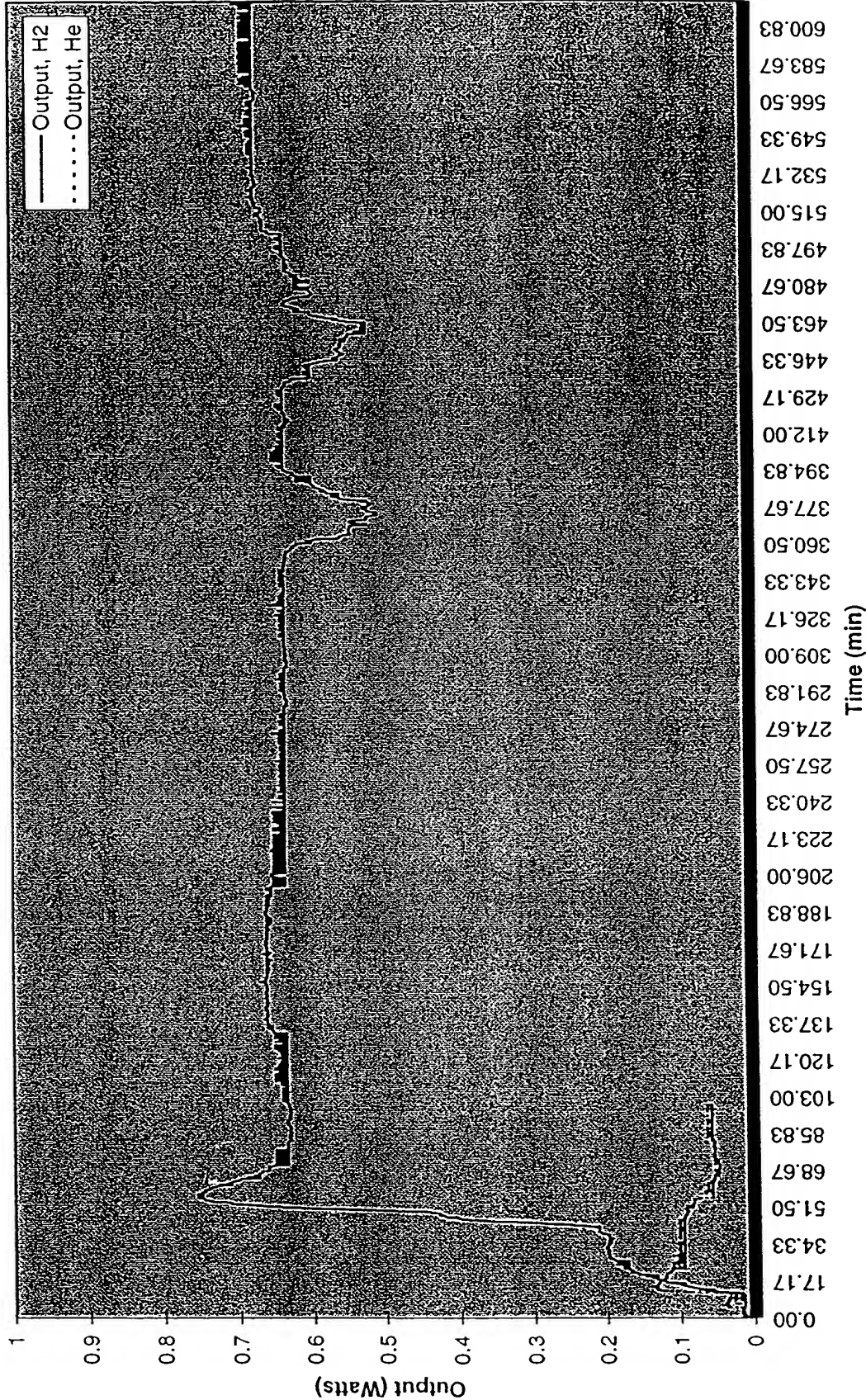


Figure 6



## **DECLARATION OF MICHAEL G. JACOX**

I, Michael G. Jacox do hereby declare and say as follows:

1. I received a Bachelor of Science Degree in Nuclear Engineering from the Georgia Institute of Technology in 1985. I received a Masters of Science Degree in Nuclear Engineering from the University of Idaho in 1992.

2. From 1998 to the present, I have been employed as an Assistant Director for the Commercial Space Center for Engineering (CSCE), Texas A & M University, where I have developed a strategic plan for a newly created NASA commercial space center which resulted in an increase of NASA funding from \$500K to \$1M annually. I planned and executed the campaign for industry input and support of the CSCE. I led the development of the first integrated payload design center at Texas A & M University.

3. From 1996-1998, I was employed as a Program Manager at the Space Dynamics Lab, Utah State University, where I defined, promoted and managed the \$50M Solar Orbit Transfer Vehicle (SOTV) space experiment and technology development program. I also completed the first ever system-level ground test of the Integrated Solar Upper State (ISUS) on time and within the \$15M budget.

4. From 1994-1996, I was employed as a Systems Engineer at Lockheed-Martin Idaho Technologies, where I managed a team of more than 30 engineers and scientists from NASA, the Naval Research Lab, Air Force Research Lab and industry in a highly successful \$1M system definition study of the ISUS space power and propulsion concept. I also managed a joint DOD-DOE nuclear bimodal systems engineering team that evaluated concepts and developed preliminary designs of combined power and propulsion reactors.

5. From 1989-1994, I was employed as a Senior Scientist at EG&G Idaho, where I conceived the design and managed the development and testing of the first integrated thermionic/heat-pipe module for nuclear bimodal applications. The multi-million dollar effort resulted in successful prototype testing. I also managed the design and installation of a unique multi-million dollar hot hydrogen test facility at the Idaho National Engineering Lab. I further originated the design of the Small-Ex-core Heat Pipe Thermionic Reactor (SEHPTR), led the SEHPTR conceptual design team, and received a patent covering the SEHPTR. I also developed and benchmarked the first three-dimensional neutronics model of the Advanced Test Reactor.

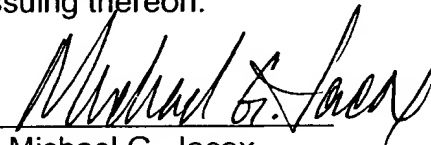
6. From 1985-1989, I was employed as a Nuclear Research Officer at USAF Weapons Lab, where I led the Air Force's space nuclear power application studies resulting in significant national program modifications and the development of the Military Space Reactor Initiatives. I also installed advanced nuclear reactor analysis codes on in-house computers.

7. While employed at EG&G, I contracted for the Idaho National Engineering Laboratory (INEL) under a DOE contract. At INEL, I conducted three experiments in which hydrogen was reacted with a catalyst, (K+, K+), generated from aqueous  $K_2CO_3$ , in an electrolytic cell containing nickel and platinum electrodes. The test conditions and results are shown in the attached report. As can be seen from the test results, 20 to 30 watts of excess heat was observed and in one instance the ratio of excess power to input electrolysis joule heating power was 850%.

8. The evidence presented in the attached report clearly demonstrates that a phenomenon takes place upon the admission of hydrogen to an electrolytic cell containing aqueous  $KCO_3$ . This phenomenon generates heat in excess of that expected from any known chemical process, given the content of the reactants in the cell. A detailed analysis of all constituents was conducted to ensure that no chemical reactions were occurring which could be generating the excess heat observed.

9. I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

By



Michael G. Jacox

Date:

25 July 00



## Experimental Verification by Idaho National Engineering Laboratory

### Methods

A search for excess heat during the electrolysis of aqueous potassium carbonate ( $K^+/K^+$  electrocatalytic couple) was investigated using cells supplied by HydroCatalysis Power Corporation and a cell fabricated by Idaho National Engineering Laboratory (INEL). To simplify the calibration of these cells, they were constructed to have primarily conductive and forced convective heat losses. Thus, a linear calibration curve was obtained. Differential calorimetry was used to determine the cell constant which, was used to calculate the excess enthalpy. The cell constant was calculated during the experiment (on-the-fly-calibration) by turning an internal resistance heater off and on, and inferring the cell constant from the difference between the losses with and without the heater.

The general form of the energy balance equation for the cell in steady state is:

$$0 = P_{\text{appl}} + Q_{\text{htr}} + Q_{\text{xs}} - P_{\text{gas}} - Q_{\text{loss}} \quad (\text{III.1})$$

where  $P_{\text{appl}}$  is the electrolysis power;  $Q_{\text{htr}}$  is the power input to the heater;  $Q_{\text{xs}}$  is the excess heat power generated by the hydrogen "shrinkage" process;  $P_{\text{gas}}$  is the power removed as a result of evolution of  $H_2$  and  $O_2$  gases; and  $Q_{\text{loss}}$  is the thermal power loss from the cell. When an aqueous solution is electrolyzed to liberate hydrogen and oxygen gases, the electrolysis power  $P_{\text{appl}} (=E_{\text{appl}}I)$  can be partitioned into two terms:

$$P_{\text{appl}} = E_{\text{appl}}I = P_{\text{cell}} + P_{\text{gas}} \quad (\text{III.2})$$

An expression for  $P_{\text{gas}} (=E_{\text{gas}}I)$  is readily obtained from the known enthalpy of formation of water from its elements:

$$E_{\text{gas}} = \frac{-\Delta H_{\text{form}}}{\alpha F} \quad (\text{III.3})$$

( $F$  is Faraday's constant), which yields  $E_{\text{gas}} = 1.48 \text{ V}$  for the reaction



The net faradaic efficiency of gas evolution is assumed to be unity; thus, Eq. (III.2) becomes

$$P_{\text{cell}} = (E_{\text{appl}} - 1.48 \text{ V})I \quad (\text{III.5})$$

The cell was calibrated for heat losses by turning an internal resistance heater off and on while maintaining constant electrolysis and by inferring

the cell constant from the difference between the losses with and without the heater where heat losses were primarily conductive and forced convective losses. When the heater was off, the losses were given by

$$c(T_C - T_b) = P_{\text{appl}} + 0 + Q_{\text{xs}} - P_{\text{gas}} \quad (\text{III.6})$$

where  $c$  is the heat loss coefficient;  $T_b$  is ambient temperature and  $T_C$  is the cell temperature. When a new steady state is established with the heater on, the losses change to:

$$c(T_C' - T_b) = P'_{\text{appl}} + Q_{\text{htr}} + Q'_{\text{xs}} - P'_{\text{gas}} \quad (\text{III.7})$$

where a prime superscript indicates a changed value when the heater was on. When the following assumptions apply

$$Q_{\text{xs}} = Q'_{\text{xs}}; P_{\text{appl}} = P'_{\text{appl}}; P_{\text{gas}} = P'_{\text{gas}} \quad (\text{III.8})$$

the cell constant or heating coefficient  $a$ , the reciprocal of the heat loss coefficient( $c$ ), is given by the result

$$a = \frac{T_C' - T_C}{Q_{\text{htr}}} \quad (\text{III.9})$$

In all heater power calculations, the following equation was used

$$Q_{\text{htr}} = E_{\text{htr}} I_{\text{htr}} \quad (\text{III.10})$$

## LIGHT WATER CALORIMETRY EXPERIMENTS

### INEL EXPERIMENT I (DC Operation)

The present experiments were carried out by observing and comparing the temperature difference,  $\Delta T_1 = T(\text{electrolysis only}) - T(\text{blank})$  and  $\Delta T_2 = T(\text{electrolysis plus resistor heating}) - T(\text{blank})$  referred to unit input power.

The cell comprised a 10 gallon (33 in. x 15 in.) Nalgene tank (Model # 54100-0010). Two 4 inch long by 1/2 inch diameter terminal bolts were secured in the lid, and a cord for a heater was inserted through the lid.

The cathode comprised 1.) a 5 gallon polyethylene bucket which served as a perforated (mesh) support structure where 0.5 inch holes were drilled over all surfaces at 0.75 inch spacings of the hole centers and 2.) 5000 meters of 0.5 mm diameter clean, cold drawn nickel wire (NI 200 0.0197", HTN36N0AG1, AI Wire Tech, Inc.). The wire was wound uniformly around the outside of the mesh support as 150 sections of 33 meter length. The ends of each of the 150 sections were spun to form three cables of 50 sections per cable. The cables were pressed in a terminal connector which was bolted to the cathode terminal post. The connection was covered with epoxy to prevent corrosion.

The anode comprised an array of 15 platinized titanium anodes (15 - Engelhard Pt/Ti mesh 1.6" x 8" with one 3/4" by 7" stem attached to the 1.6" side plated with 100 U series 3000). A 3/4" wide tab was made at the end of the stem of each anode by bending it at a right angle to the anode. A 1/4" hole was drilled in the center of each tab. The tabs were bolted to a 12.25" diameter polyethylene disk (Rubbermaid Model #2666) equidistantly around the circumference. Thus, an array was fabricated having the 15 anodes suspended from the disk. The anodes were bolted with 1/4" polyethylene bolts. Sandwiched between each anode tab and the disk was a flattened nickel cylinder also bolted to the tab and the disk. The cylinder was made from a 7.5 cm by 9 cm long x 0.125 mm thick nickel foil. The cylinder traversed the disk and the other end of each was pressed about a 10 A /600 V copper wire. The connection was sealed with

Teflon tubing and epoxy. The wires were pressed into two terminal connectors and bolted to the anode terminal. The connection was covered with epoxy to prevent corrosion.

Before assembly, the anode array was cleaned in 3 M HCl for 5 minutes and rinsed with distilled water. The cathode was cleaned in 3% H<sub>2</sub>O<sub>2</sub>/ 0.57 M K<sub>2</sub>CO<sub>3</sub> and rinsed with distilled water. The anode was placed in the cathode support and the electrode assembly was placed in the tank containing electrolyte. The power supply was connected to the terminals with large cables.

The electrolyte solution comprised 28 liters of 0.57 M K<sub>2</sub>CO<sub>3</sub> (Alfa K<sub>2</sub>CO<sub>3</sub> 99%) in the case of the MC 3 cell or 28 liters of 0.57 M Na<sub>2</sub>CO<sub>3</sub> (Alfa Na<sub>2</sub>CO<sub>3</sub> 99%) in the case of the MC 2 cell.

The heater comprised a 57 ohm 1500 watt Incoloy coated cartridge heater which was suspended from the polyethylene disk of the anode array. It was powered by a regulated power supply. The voltage was measured with a digital meter, and the current was measured as a voltage across a precision resistor with a digital meter.

The stirrer comprised a 1 cm diameter by 43 cm long glass rod to which an 8 cm by 2.5 cm Teflon half moon paddle was fastened at one end. The rod passed through a bearing hole in the tank lid and through a bearing hole in the center of the anode array disk. The other end of the stirrer rod was connected to a variable speed stirring motor. The stirrer shaft was rotated at 4 Hz. With the stirrer connected, the stirrer motor drew 4.7 W. With the stirrer disconnected, the stirrer drew 4.4 W; thus, 0.3 W was the stirrer power.

Electrolysis was performed at 39.5 amps constant current with a constant current power supply. The cells were operated in the environmental chamber in the INEL Battery test Laboratory. The chamber maintained the average temperature of the cell surroundings within 1 °C. The bottom of the cell rested on a 1/2 inch thick sheet of Styrofoam.

The temperature was recorded with a series of Teflon-coated Type E thermocouples inserted in several places. The ambient temperature reference was a closed one-liter container of water

with a thermocouple nominally in the center of the water volume.

Data from thermocouples, voltages, and currents were logged by one of the Battery Lab's computer based data systems and recorded at 5 minute intervals. The delta temperature ( $\Delta T = T(\text{electrolysis only}) - T(\text{blank})$ ) and electrolysis power were plotted. The heating coefficient was determined "on the fly" by the addition of heater power. The delta temperature  $\Delta T_2 = T(\text{electrolysis} + \text{heater}) - T(\text{blank})$  and the electrolysis power and heater power were plotted.

Mass spectroscopy of the gasses evolving from the MC 3 ( $\text{K}_2\text{CO}_3$ ) cell was performed using a VG Instruments model SXP-50 high -precision mass spectrometer with 0.01-amu mass resolution and 6 decade sensitivity.

A 100 ml sample of the 0.57 M  $\text{K}_2\text{CO}_3$  electrolyte of the MC 3 ( $\text{K}_2\text{CO}_3$ ) cell was removed after 20 days of cell operation, and a chemical analysis was performed on the electrolyte using an Inductively Coupled Plasma-Atomic Emission Spectrometer.

## RESULTS

### Light Water Calorimetry

The results of the electrolysis for INEL cell runs MC 2 and MC 3 at 39.5 A constant current appear in Figure 1 (hand plot of data by INEL scientists). As shown in Figure 1, the MC 3 ( $\text{K}_2\text{CO}_3$ ) cell intercepts the Total Input Power axis at 35 W; whereas, the MC 2 ( $\text{Na}_2\text{CO}_3$ ) cell intercepts the Total Input Power axis at 59 W. The input power to electrolysis gases given by Eqs. (III.2-III.5) is  $(39.5)(1.48) = 58.5$  W. The production of excess enthalpy of 25 W is observed with the MC 3 ( $\text{K}_2\text{CO}_3$ ) cell, and energy balance is observed with the MC 2 ( $\text{Na}_2\text{CO}_3$ ) cell.

Mass spectroscopic analysis of the gasses evolved by the MC 3 ( $\text{K}_2\text{CO}_3$ ) cell showed that a significant fraction of the sample was air with standard constituents. When the spectrum associated with air was removed, the residue showed a majority of diatomic hydrogen and oxygen gases in approximately the 2:1 proportion expected from the electrolysis and residual water vapor. There were no hydrocarbons, no metallic constituents or other anomalies except that a slightly higher than expected hydrogen to oxygen ratio was observed. No

tritium or deuterium measurements above normal background were observed.

Chemical analysis of an electrolyte sample from the MC 3 ( $K_2CO_3$ ) cell after 20 days of operation found the following components at levels above the background levels in the water used to fill and replenish the cell: 1.7 ppm silicon, 1.1 ppm sulfur, and 46.5 ppm sodium in addition to the  $K_2CO_3$  salt. Small quantities of silicon are known impurities in the nickel wire and may have also come from the glassware used in various processes. Sulfur is a common impurity in the salt, and it may have come from the resin beds used for water deionization. Sodium is a probable salt impurity, and it may also have come from hand contact with the system. The potassium was measured at 43,000  $\mu\text{g/ml}$  corresponding to a salt molarity of 0.55 M (within measurement error of the initial 0.57 molarity determined by weighing the salt and measuring the water for the initial charge). The electrolyte retained its molarity. The cell potential characteristics were essentially unchanged over the duration of operation. There were no nickel or other metallic compounds present in the electrolyte. A visual inspection of the cell showed that all of the structural components were intact. The cell comprised about 155 moles of nickel in the cathode, about 6.5 moles of titanium in the anodes, and about 13.7 moles of  $K_2CO_3$ . The only material consumed in the cell was nano-pure deionized water.

## **INEL EXPERIMENT II (Pulsed Power Operation)**

The MC 3 ( $K_2CO_3$ ) cell was wrapped in a one-inch layer of urethane foam insulation about the cylindrical surface. The top was not insulated. The bottom of the cell rested on a 1/2 inch thick sheet of Styrofoam.

The cell was operated in a pulsed power mode. A current of 10 amperes was passed through the cell for 0.2 seconds followed by 0.8 seconds of zero current for the current cycle. The cell voltage was about 2.4 volts, for an average input power of 4.8 W. The electrolysis power average (Eq. (III.5)) was 1.84 W, and the stirrer power was measured to be 0.3 W. Thus, the total average net input power was 2.14 W. The cell was operated at various resistance heater settings, and the temperature

difference between the cell and the ambient as well as the heater power were measured.

## **RESULTS**

### **Light Water Calorimetry**

The results of the excess power as a function of cell temperature with the MC 3 cell operating in the pulsed power mode at 1 Hz with a cell voltage of 2.4 volts, a peak current of 10 amperes, and a duty cycle of 20 % appears in Figure 2.

Figure 2 shows that the excess power is temperature dependent for pulsed power operation, and the maximum excess power shown in Figure 2 is 18 W for an input electrolysis joule heating power of 2.14 W. Thus, the ratio of excess power to input electrolysis joule heating power is 850 %.

### **INEL EXPERIMENT III (Forced Convection Calorimetry Of INEL Cell)**

INEL scientists constructed an electrolytic cell comprising a nickel cathode, a platinized titanium anode, and a 0.57 M  $K_2CO_3$  electrolyte. The cell design appears in Appendix 1. The cell was operated in the environmental chamber in the INEL Battery test Laboratory at constant current, and the heat was removed by forced air convection in two cases. In the first case, the air was circulated by the environmental chamber circulatory system alone. In the second case, an additional forced air fan was directed onto the cell.

The cell was equipped with a water condensor, and the water addition to the cell due to electrolysis losses was measured.

## **RESULTS**

### **Light Water Calorimetry**

The data of the forced convection heat loss calorimetry experiments during the electrolysis of a 0.57 M  $K_2CO_3$  electrolyte with the cell appears in Table 1 and Figure 3. The comparison of the calculated and measure water balance of the INEL cell appears in Table 2 and Figure 4.

The intercept of the Net Input Power (calculated using Eq. (III.5)) axis of Figure 3 for both cases of forced convection is 13 W. Thus, 13 W of excess power was produced by the INEL cell. This excess power can not be attributed to recombination of the hydrogen and oxygen as indicated by the

equivalence of the calculated and measured water balance as shown in Figure 4.



Figure 1.

# THERMAL CONDUCTANCE CALIBRATION (11/25)

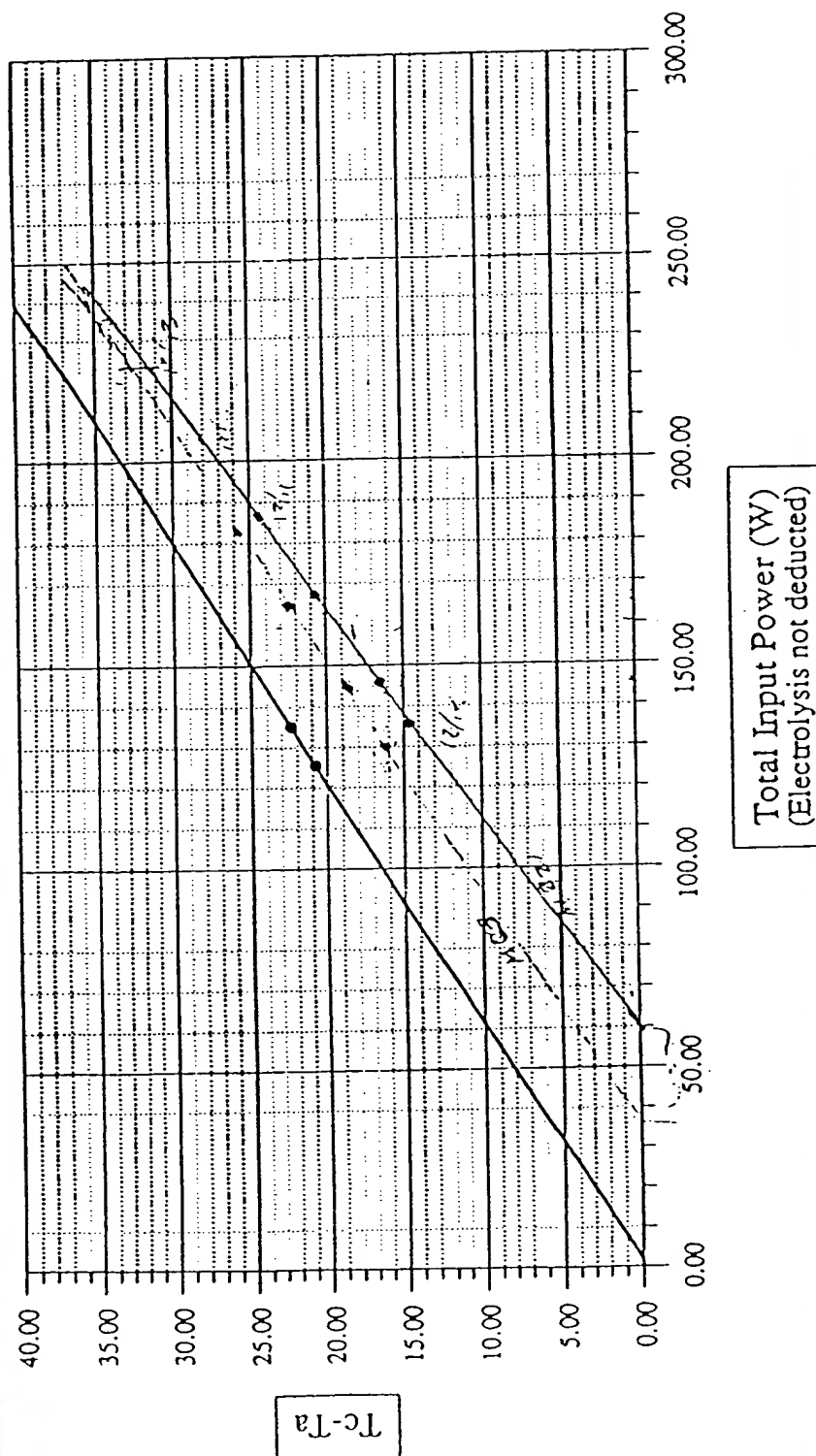


Figure 2.

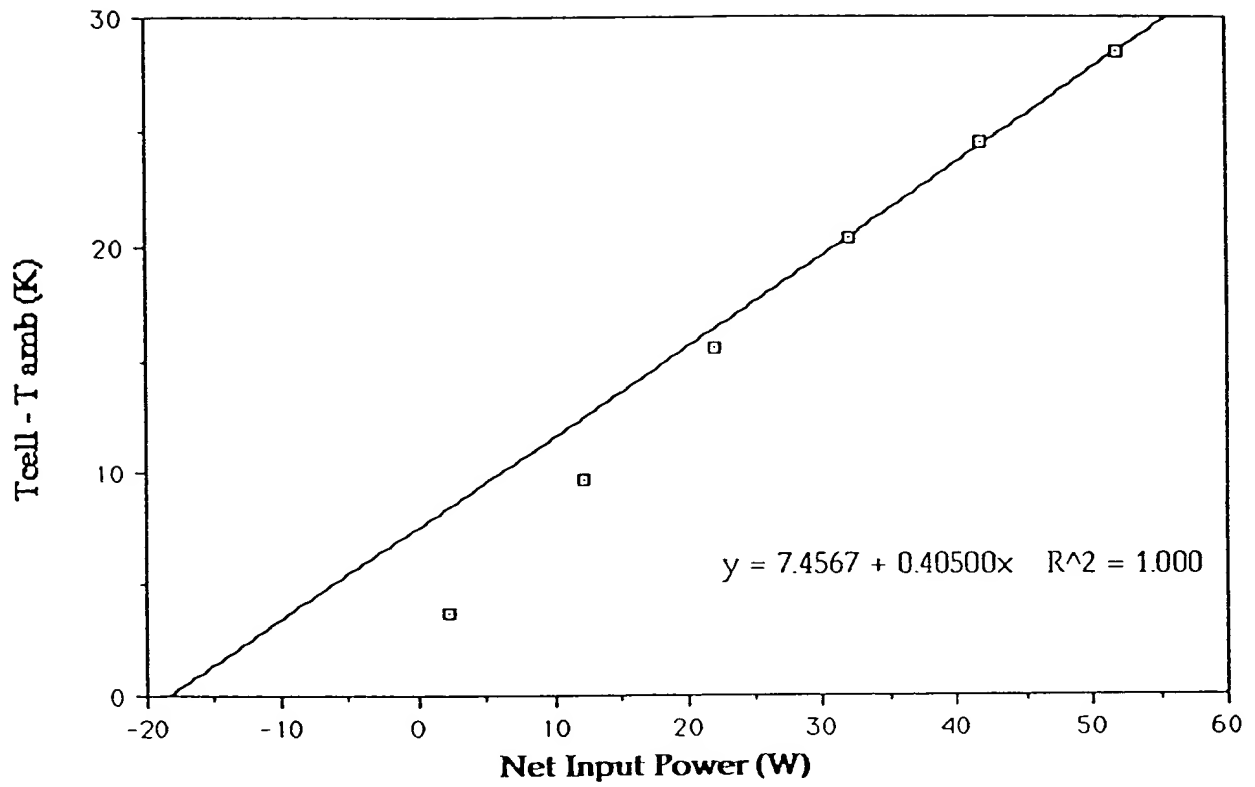
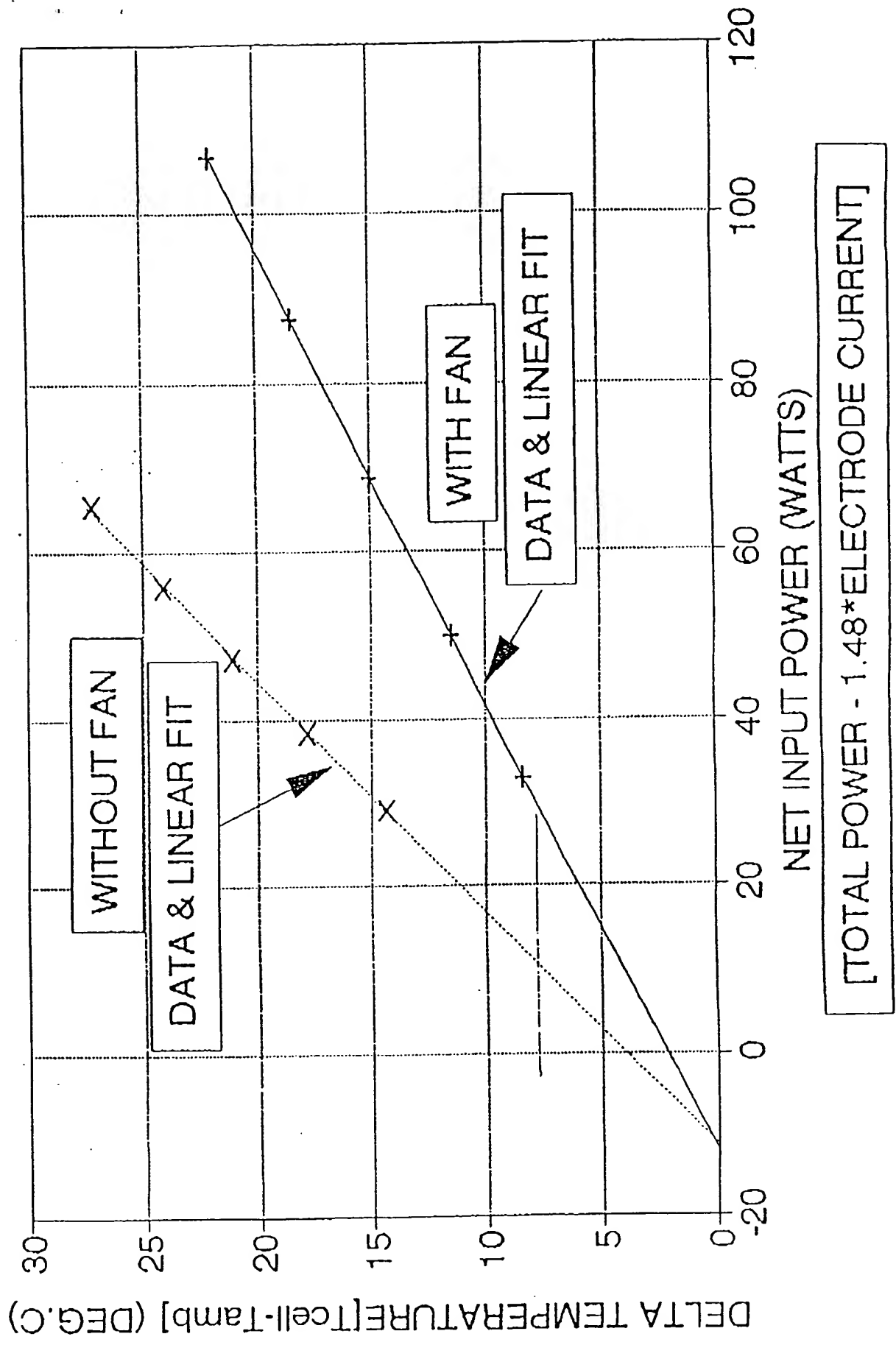


Figure 3.

# IC1 T99 THRU T103 & T105 THRU T109



# IC1 WATER ADDITION

1/9/93 THRU 1/29/93

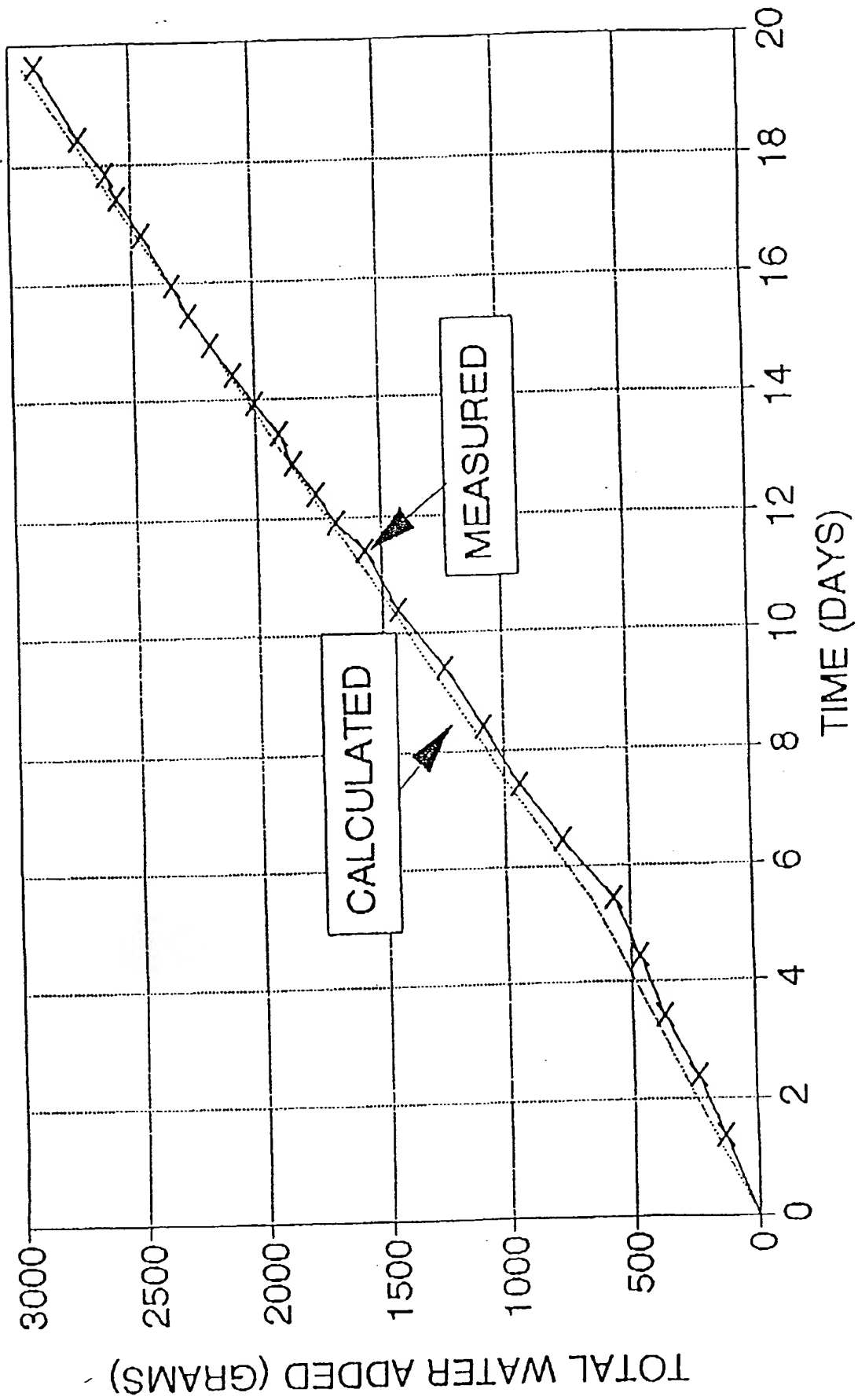


Table 1.

FILE IC1

TEST NO.	TOTAL POWER	DELTA TEMP	LF DT	DELTA TEMP	LF DT	PWR-A*1.48
T99	94.8	27.2	27.36265			65.2962
T100	85.2	24.05	23.93155			55.6962
T101	76.8	21.05	20.92933			47.2962
T102	67.8	17.75	17.71267			38.2962
T103	58.57	14.3	14.4138			29.0662
	18.24		-0.00042			-11.2638
T105	136.07			21.95	21.94573	106.6662
T106	117.05			18.42	18.42674	87.5462
T107	98.25			14.95	14.94844	68.7462
T108	79.45			11.47	11.47015	49.9462
T109	62.68			8.35	8.348937	33.0762
	17.45				-0.00082	-12.0538

Table 2.  
ICI WATER ADDITION; FILE ICI WATER

DATE	HOURS	TIME MINUTES	SECONDS	QPRO TIME	QPRO DATE+TIM	DATE-START DAYS	ELEOTRO AMP8	WATER GRAM8	WATER TOTAL	WATER CALO	TOTAL CALC	ADDED/CALC
01/09/93	21	30	0	0.886833	33978.9	-0.00416667	16	0	0	0	0	
01/11/93	7	15	0	0.302083	33980.3	1.402083333	13	131	131	169.9935	169.9935	0.77081781
01/12/93	7	10	0	0.298811	33981.3	2.398811111	18	108	239	120.4845	290.468	0.82283844
01/13/93	7	20	0	0.311808	33982.31	3.411808556	14.94	131	370	121.9893	412.4473	0.89706429
01/14/93	7	55	0	0.330558	33983.33	4.430558556	14.94	89	459	122.6582	535.1066	0.85777747
01/15/93	7	50	0	0.328388	33984.33	5.428388889	14.93	102	561	118.8188	654.9243	0.8586875
01/16/93	8	28	0	0.351389	33985.35	6.461388889	18.93	205	766	184.6302	819.5646	0.93465404
01/17/93	8	19	0	0.346628	33985.36	7.446627778	19.93	168	934	169.8341	979.3887	0.95368891
01/18/93	7	42	0	0.320833	33987.32	8.420833333	19.94	160	1084	158.5685	1135.953	0.98428301
01/19/93	7	32	0	0.313888	33988.31	9.413888889	19.93	164	1238	159.4995	1295.458	0.95884903
01/20/93	7	25	0	0.309028	33989.31	10.40902778	19.94	194	1432	139.9143	1455.369	0.98394292
01/21/93	7	42	0	0.320833	33990.32	11.42083333	19.93	133	1566	182.511	1617.88	0.96731826
01/21/93	19	28	0	0.811111	33990.81	11.81111111	19.93	110.5	1675.5	79.7469	1695.626	0.95754829
01/22/93	7	32	0	0.313889	33991.31	12.41388889	19.93	83	1758.5	80.76359	1777.379	0.98937791
01/22/93	19	37	0	0.817381	33991.82	12.81738111	19.93	92	1850.5	80.88513	1858.245	0.958323
01/23/93	7	32	0	0.313888	33992.31	13.41388889	19.94	48	1898.5	79.78976	1938.034	0.97856882
01/23/93	19	19	0	0.804861	33992.8	13.80486111	19.93	102	1998.5	78.86744	2018.892	0.98088111
01/24/93	7	28	0	0.311111	33993.31	14.41111111	19.93	84	2082.5	81.31128	2098.203	0.99281693
01/24/93	19	20	0	0.805558	33993.81	14.80555856	19.93	93	2175.5	79.41813	2177.818	0.98902727
01/25/93	7	38	0	0.318035	33994.32	15.41803556	19.93	94	2269.5	82.31512	2250.933	1.00423318
01/25/93	20	-1	0	0.834028	33994.83	15.83402778	19.93	86	2334.5	82.87281	2342.806	0.99845461
01/26/93	18	31	0	0.888184	33995.89	16.78818444	18.93	122	2456.5	137.1919	2479.898	0.99052498
01/27/93	7	45	0	0.322817	33996.32	17.42281667	18.93	86	2552.5	101.9458	2581.944	0.98859824
01/27/93	17	35	0	0.732839	33996.73	17.83283889	19.94	59	2608.5	85.8408	2647.784	0.98516331
01/28/93	7	47	0	0.324306	33997.32	18.42430556	19.93	107	2715.5	85.03047	2742.815	0.99004131
01/29/93	12	50	0	0.634722	33998.53	19.03472222	19.94	171	2886.5	184.5085	2937.323	0.98289741

Appendix I.

DATE: December 15, 1992  
TO: Richard Deaton MS 4139, Ext. 6-2016, FAX 6-2681  
FROM: R. L. Drexler MS 3123, Ext. 6-1789  
SUBJECT: INEL CELL CATHODE ESTIMATE

Attached are the following sketches and revised sketches:

Cathode Assembly for INEL CELL	12/15/92
Narrow Cathode Strap for INEL CELL	12/15/92
Cathode C-1 INEL CELL	12/2/92
Mandrel - Cathode Winding	12/8/92
Electrode Bus Ring INEL CELL	12/15/92

Would you please give us a firm estimate for fabrication of two "identical" cathode assemblies per the 12/15/92 sketch, and two Electrode Bus Rings per the 12/15/92 sketch.

The cathode windings could be made on a mandrel per the sketch 12/8/92 or similar suitable arrangement.

These cathodes and bus rings are similar to those previously fabricated except:

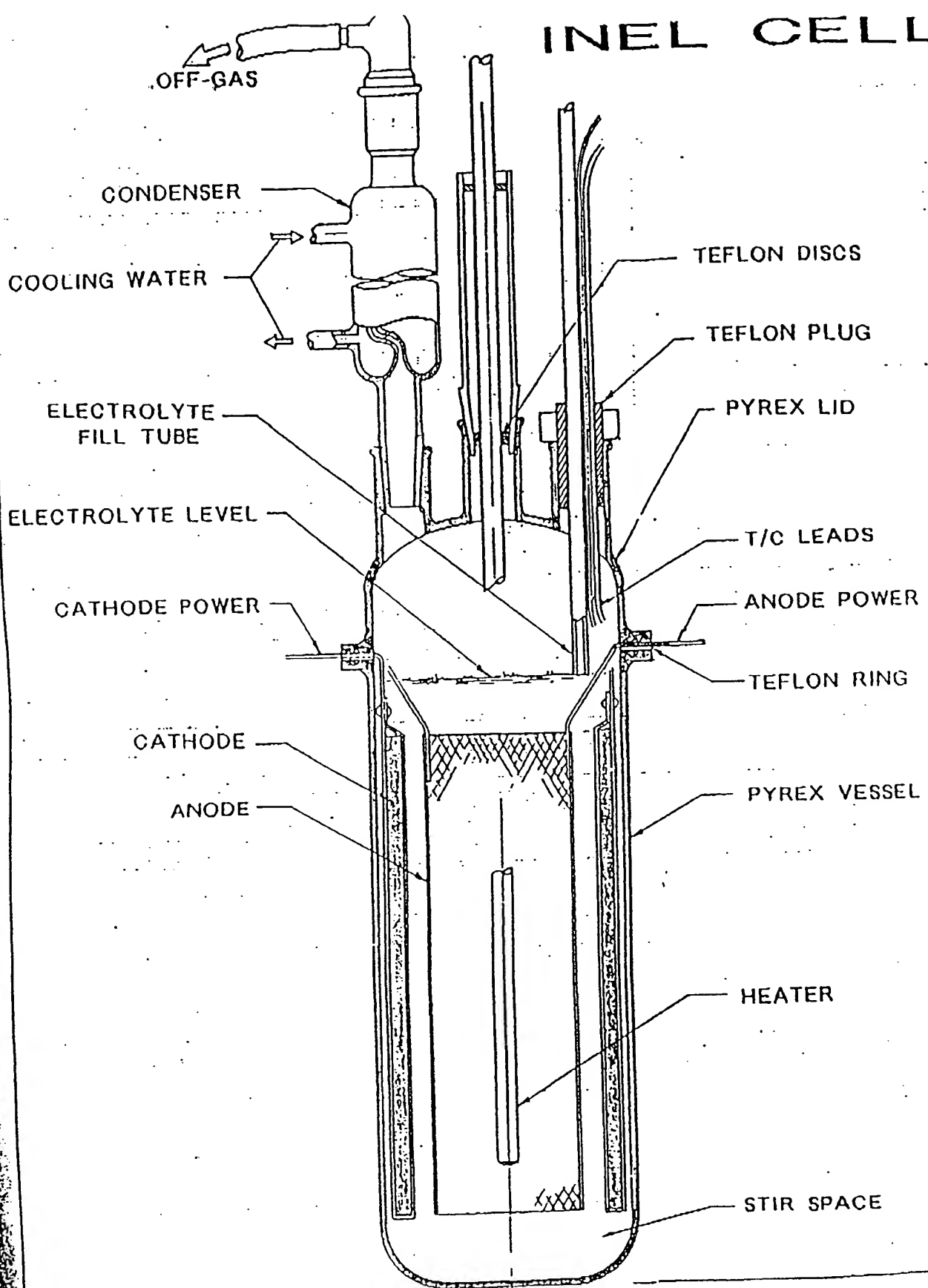
1. The straps are 0.5 in. wide rather than 1.0 in. wide. These narrower straps would be flat rather than arched to fit the winding curvature.
2. There are no secondary straps as were added to the windings of the first cathode assembly.
3. Windings would be less dense than the first winding. A much steeper pitch is probably necessary to achieve the more open wind.
4. Weight of the NI-200 wire of each winding should be very close to 3.33 pounds, and both windings should have the same weight as closely as possible.
5. Slots in the Teflon Bus Ring for the cathode straps would be 0.50 wide rather than the 1.0 width of the first ring.

FEB 04 '93 05:11PM OSTA

P.3/6

INEL CELL

# INEL CELL

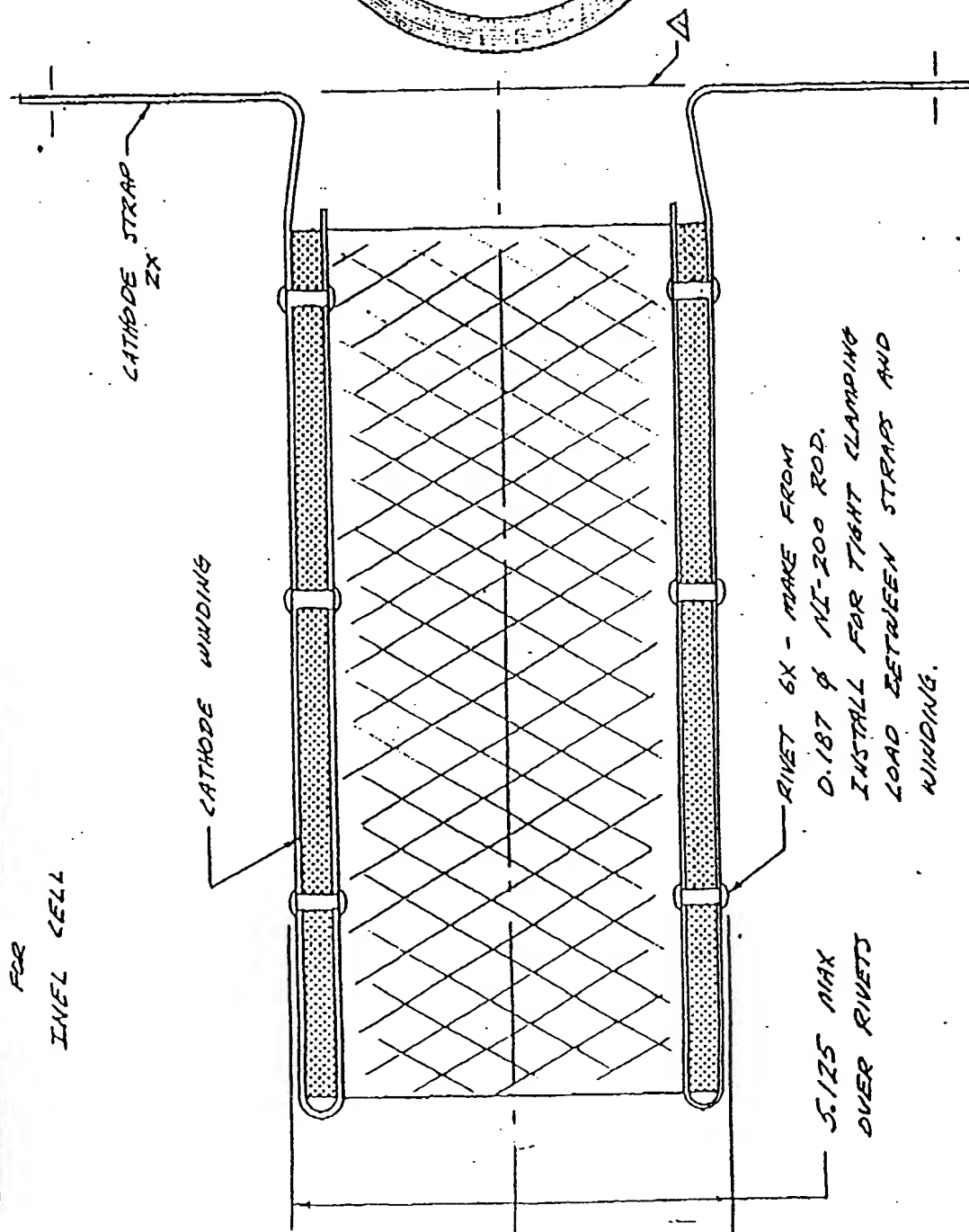


0 1 2 3 4 5 6  
INCHES



# CATHODE ASSEMBLY

FOR  
INEL CELL

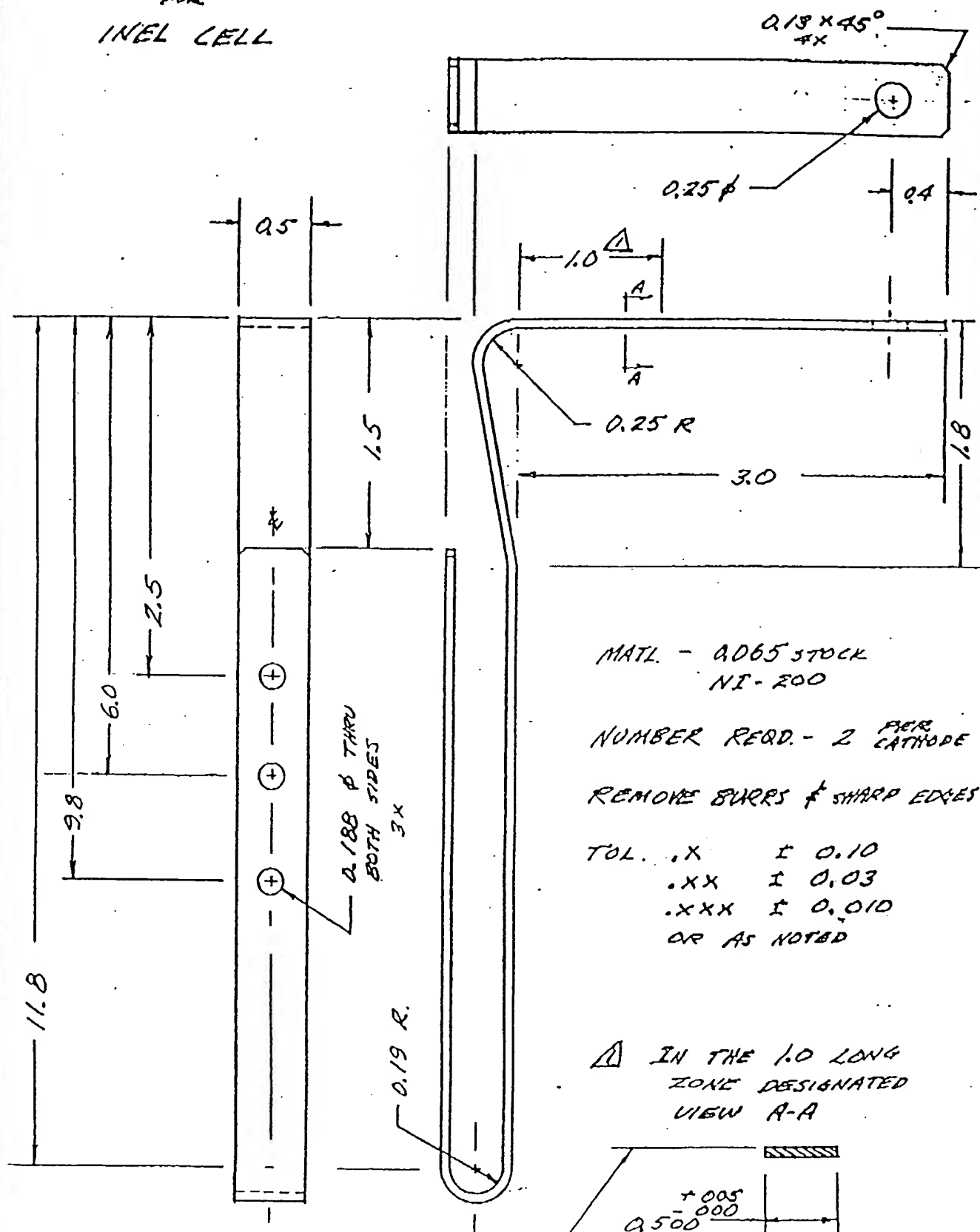


△ ALIGN BOTH STRAPS  
IN PLANE AT 90°  
WITH WINDING &

# NARROW CATHODE STRAP

12-15-92

FOR  
INEL CELL



SCALE - FULL

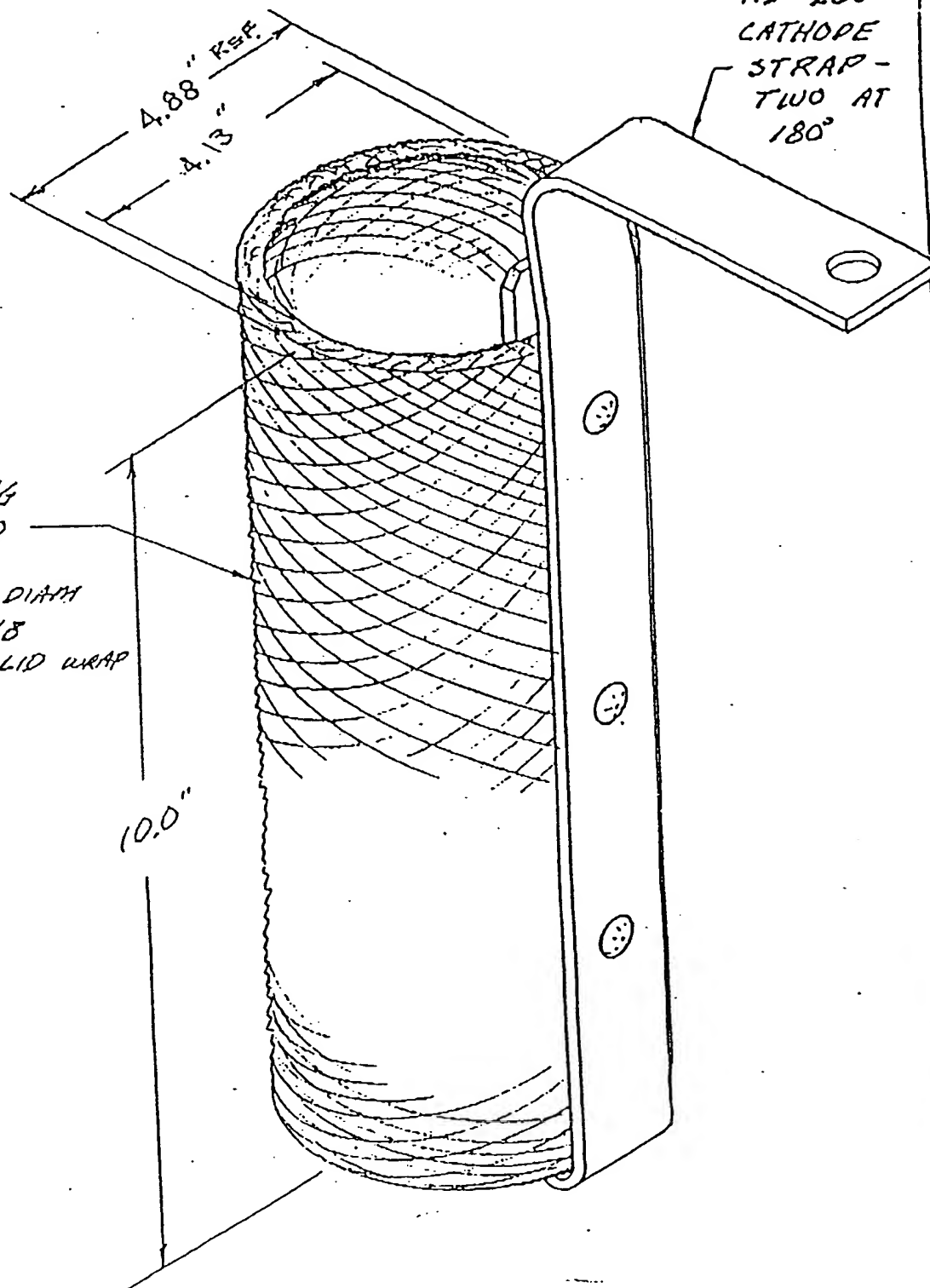
10-A92  
10-21-92  
12-2-95

# CATHODE C-1

INEL CELL

NI-200  
CATHODE  
STRAP -  
TWO AT  
180°

WINDING  
NI-200  
WIRE  
0.010 DIAM  
3.33 LB  
0.2 SOLID WRAP



NUMBER RECD. - ONE PER CELL

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